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Identification of Sources of Particulates for St. Joseph, Missouri

PEDCo-Environmental, Inc.
Kansas City, MO

Prepared for

Environmental Protection Agency
Kansas City, MO

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February 1981

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16. ABSTRACT

St. Joseph, Missouri has been designated a particulate nonattainment area. Identification of particulate sources was necessary in order to develop particulate control measures. Five techniques were used: (1) statistical analyses of historic particulate sampling data; (2) microinventories around sampling sites and evaluation with the empirical modeling technique; (3) short-term particulate sampling at additional locations; (4) chemical and microscopic evaluations of particulate samples; and (5) evaluation of major point sources. The analysis indicated that 24 to 35 percent of the particulate concentration at urban sites is generated by St. Joseph area sources as opposed to extra-regional sources. Specific sources identified by location are reentrained dust from streets, automobile emissions, industrial process and point source emissions, and exposed areas.

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by

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SECTION 1

EXECUTIVE SUMMARY

St. Joseph, Missouri, has been designated a particulate nonattainment area, based on recently measured violations of the National Ambient Air Quality Standards. Therefore, the Missouri Department of Natural Resources (DNR), Air Pollution Control Program, must prepare a State Implementation Plan (SIP) describing particulate control measures aimed at attainment of the particulate air quality standards. Little is known about particulate emission sources in the St. Joseph area. Identification of particulate sources is requisite information for developing particulate control measures.

The objective of this study was to use several different analytical techniques to identify the particulate sources contributing to TSP concentrations above the primary standard in St. Joseph. These techniques are listed below:

1. Statistical analyses of historical particulate sampling data aimed at source identification and other factors affecting measured concentrations.

2. Microinventories of particulate sources around five particulate sampling locations, and evaluation of inventory data using the empirical modeling technique.

3. Short-term particulate sampling at additional locations in the St. Joseph area.

4. Chemical and microscopic evaluation of selected particulate samples taken at five locations in the St. Joseph area.

5. Evaluation of all major point sources in the St. Joseph area to determine whether present control equipment meets Reasonably Available Control Technology (RACT).

These techniques were focused on answering two questions:

1. Is the particulate problem in St. Joseph due to extraregional sources or sources in the St. Joseph area? An unknown part of the total concentration may be due

to long-range transport from Kansas City or from rural fugitive dust. Both of these source categories are beyond the control of St. Joseph enforcement agencies.

2. If a part of the particulate concentration is due to sources within the St. Joseph area, what are the specific sources? Identification of specific St. Joseph sources will allow design of specific control measures that can be implemented by local agencies.

Sections 2 through 6 contain the results of the five techniques. Each technique was used to analyze the available data independently of the other techniques. Conclusions based solely on one technique occasionally were not in complete agreement with conclusions reached solely by one of the other techniques.

Section 7 contains a synthesis of the results of all techniques. In answer to the first question, all five analytical techniques indicated that local sources increased particulate concentrations. At the Eighth and Edmond, Lake Road Sewage Treatment Plant, and the fire station particulate monitoring sites, at least 24 to 35 percent of the particulate concentration is locally generated.

In answer to the second question, the type of local particulate source varied by particulate monitor location. The Eighth and Edmond and fire station sites are heavily impacted by reentrained dust from streets and automobile emissions. The Eighth and Edmond site is also impacted by industrial process and point source emissions. The Lake Road site is impacted by emissions from the St. Joseph area industrial processes, exposed areas, and point sources, with a lesser contribution from traffic sources. The Faraon Street and Rosecrans Airport sites, which are on the periphery of St. Joseph, showed fewer local source impacts.

SECTION 2

STATISTICAL ANALYSIS

DATA BASE

Particulate Sampling Data

Particulate sampling data from four sites were used. Data from three St. Joseph sites were available from the Missouri DNR and include two operative and one discontinued monitoring site. The two operative sites are the Eighth and Edmond Streets site in the downtown area, and the Lake Road Sewage Treatment Plant site (STP), which is located on the southwestern edge of St. Joseph. Until the end of 1977, the discontinued site was located near a shopping center at the intersection of Belt Highway and Frederick Boulevard. To serve as a background site (i.e., a site not directly influenced by particulate sources) and to assist in answering the long-range-transport question, data from the Kansas City International Airport (KCI) site, 11500 North 71 Highway, were used as the fourth site. This site is located 35 miles south of St. Joseph. The KCI data were provided by the Kansas City, Missouri Health Department, Air Quality Program. Table 1 gives an annual summary of the data base for each site. Figure 1 shows the location of the three sites in St. Joseph.

One problem encountered with the TSP data was the large number of missing samples. In only 5 of the 11 years of data gathering at the Eighth and Edmond and Lake Road STP sites were more than 75 percent (45 of 60 samples) of the total possible samples collected. Samples were collected every sixth day. This lack of samples made some analyses difficult or impossible to perform. A discussion of how sample size affected each analysis is given in the next subsection along with the description of each test.

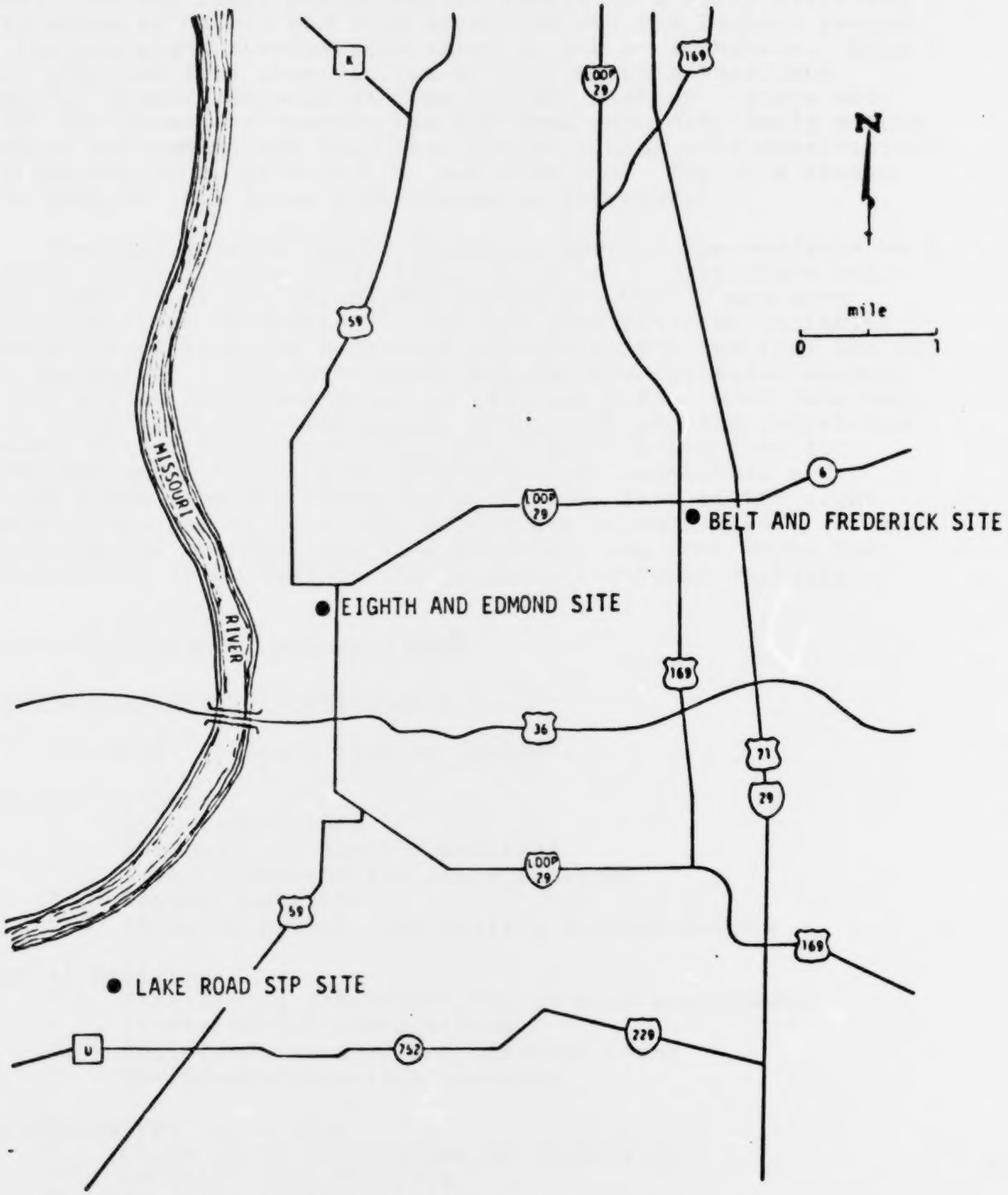
Another problem was encountered involving sampler running times. Several samples had hi-vol running times other than 24 hours, with times ranging from 16 to 120 hours. This made data correlation of daily measurements invalid in certain instances.

Meteorological Variables

Meteorological data were obtained from Local Climatological Data (LCD) summaries compiled by the National Weather Service

TABLE 1. SUMMARY OF TSP DATA AVAILABLE FOR ANALYSIS

Site	Year	No. of samples	Highest reading, μg/m³	Lowest reading, μg/m³	Annual geometric mean, μg/m³
Eighth and Edmond	1973	23	420.4	21.0	70.8
	1974	57	246.3	12.4	57.6
	1975	56	176.8	33.9	79.7
	1976	61	232.8	32.7	82.0
	1977	55	257.4	14.9	83.6
	1978	43	400.7	28.7	94.8
	1979	36	277.7	12.3	84.3
Lake Road Sewage Treatment Plant	1976	21	208.9	43.3	94.3
	1977	54	159.6	13.4	68.1
	1978	44	318.8	14.6	78.8
	1979	37	268.3	16.1	83.5
Belt and Frederick	1975	58	182.6	24.3	74.4
	1976	61	202.0	33.1	82.7
	1977	31	260.3	31.0	99.0
Kansas City International Airport	1974	42	141.0	8.0	42.5
	1975	54	125.0	8.0	46.4
	1976	48	164.0	16.0	50.0
	1977	43	125.0	8.0	42.0
	1978	38	106.0	14.0	49.2
	1979	46	159.0	20.0	56.5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EIGHTH AND EDMOND SITE
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169
LAKE ROAD STP SITE
U
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229

Figure 1. St. Joseph TSP monitoring sites with historical data.

(NWS). An LCD lists precipitation totals on a daily basis and also gives windspeed and wind direction for the 24-hour period by listing eight observations taken at 3-hour intervals. Data were compiled from observations at St. Joseph's Rosecrans Memorial Airport as well as from the KCI station. Since mid-1975, the Rosecrans station has not been recording daily precipitation totals and has only been taking 3-hour wind observations between the hours of 6:00 a.m. and 9:00 p.m. For this reason, data from KCI had to be substituted as necessary.

The four meteorological variables used in the analysis were 24-hour precipitation total (days >0.10 in.), days since rainfall (DSR) >0.01 in., windspeed (miles per hour), and wind direction (tens of degrees). The two precipitation variables were obtained from the Rosecrans LCD until 1975 and from the KCI LCD thereafter. The correlation between precipitation amounts at KCI and at Rosecrans prior to 1975 was 0.85. Wind data were also taken from KCI observations after 1975 and the correlation between data from the two sites prior to 1975 was 0.89 for windspeed and 0.91 for wind direction. To constitute a day having winds from a predominant direction, five of the eight observations had to be within 60 degrees of each other. If this criterion was not met, the wind direction was considered too inconsistent to be used in any of the directional analyses.

STATISTICAL EVALUATIONS PERFORMED

Selection of Analysis Techniques

Potential analyses were as follows:

Temporal patterns
- Long-term trends
- Seasonal and monthly patterns
- Weekday/weekend and daily patterns
- Diurnal patterns
- Emission pattern/air quality relationships

Spatial patterns
- Stratifying concentrations by site environment
- Intersite TSP correlations
- Pollution, dosage, and gradient roses
- Upwind/downwind relationships

Meteorological variations
- Correlation and regression techniques
- Decision tree analysis
- Analysis of precipitation
- Analysis of windspeed
- Trajectory analysis

Three of the possible five analyses of temporal pattern methods could not be used. The analysis of long-term trends was not possible since no site had data for at least 5 years with more than the 45 samples required to make it a statistically valid year. The analysis of diurnal variation could not be performed since all of the historical TSP data obtained were 24-hour concentrations. An emission pattern/air quality relationship could not be derived without source emissions from specific sampling days.

Conceptually, all four of the spatial analysis methods were used, although only two of the methods were used in their entirety. The stratification of concentrations by site environment was not used in any calculations. When the results of other methods were interpreted, however, the site environment was often considered an important factor. Similarly, no direct upwind/downwind relationships were drawn, but the location of sites in relation to one another occasionally presented an upwind/downwind comparison that assisted in the interpretation of results.

Three meteorological assessment methods could not be utilized. Decision tree analysis required meteorological data that were not available. Analysis of windspeed was not performed because earlier analysis indicated that windspeed was not a significant factor. Trajectory analysis required meteorological data such as upper air windspeeds and wind directions that were too costly to obtain.

Application of Analysis Techniques

Seasonal Patterns--

This technique allows indirect identification of major sources or source categories by examining the temporal fluctuation in total suspended particulate (TSP) concentrations. For example, concentrations at urban sites tend to increase during the winter months in cold climates due to space heating and reentrained dust from streets where abrasives are used. In nonurban areas, concentrations tend to increase in summer months due to fugitive and windblown dust, and agricultural activities. A minimum of 3 years of data is required for the analysis.[1]

Quarterly geometric means were computed from all the years of data available at each site. Tables 2 through 5 show the quarterly means that were calculated and the sample size for each of the sites. Weighted means were determined for each of the seasons from the sets of quarterly geometric means. These weighted means of quarterly TSP concentrations for each quarter and each site were then plotted in Figure 2.

The four plots in Figure 2 can be divided into two types. The Eighth and Edmond and Belt and Frederick curves both represent urban traffic-impacted sites. Both of these sites display

TABLE 2. QUARTERLY TSP GEOMETRIC MEANS AT EIGHTH AND EDMOND SITE, 1974-1979

Year	First quarter		Second quarter		Third quarter		Fourth quarter	
	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³
1974	14	70.2	15	61.0	14	70.8	14	29.7
1975	13	88.6	15	78.8	15	83.4	13	74.2
1976	16	95.8	15	70.1	15	69.8	15	95.5
1977	15	101.6	14	92.1	14	72.9	12	68.5
1978	14	86.5	11	110.5	12	99.1	6	81.2
1979	11	78.0	12	85.0	10	113.4	3	86.5
Total	83		82		80		63	
Weighted mean		88.5		81.1		82.2		67.4

TABLE 3. QUARTERLY TSP GEOMETRIC MEANS AT LAKE ROAD SEWAGE TREATMENT PLANTSITE, 1976-1979

Year	First quarter		Second quarter		Third quarter		Fourth quarter	
	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³
1976			10	99.2	7	115.2	4	58.7
1977	14	65.7	15	81.3	13	74.5	12	51.6
1978	13	55.2	9	104.2	10	103.0	12	61.6
1979	11	57.9	11	88.7	10	102.6	5	108.9
Total	38		45		40		33	
Weighted mean		61.5		91.7		95.8		64.8

TABLE 4. QUARTERLY TSP GEOMETRIC MEANS AT BELT HIGHWAY AND FREDERICK BOULEVARD SITE, 1975-1977

Year	First quarter		Second quarter		Third quarter		Fourth quarter	
	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³	No. of samples	TSP, μg/m³
1975	13	96.4	15	71.4	15	72.5	15	63.5
1976	16	95.9	15	70.6	15	74.5	15	91.8
1977	14	102.9	14	95.8	13	97.0		
Total	43		44		43		30	
Weighted mean		98.3		78.9		80.6		77.7

TABLE 5. QUARTERLY TSP GEOMETRIC MEANS AT KANSAS CITY INTERNATIONAL AIRPORT SITE, 1974-1979

Year	First quarter		Second quarter		Third quarter		Fourth quarter	
	No. of samples	TSP, $\mu g/m^3$	No. of samples	TSP, $\mu g/m^3$	No. of samples	TSP, $\mu g/m^3$	No. of samples	TSP, $\mu g/m^3$
1974	12	31.2			14	64.7	16	37.2
1975	13	34.0	14	44.6	12	68.6	15	46.0
1976	15	38.4	15	50.0	7	73.3	11	56.0
1977	13	46.0	7	53.6	11	45.0	12	31.0
1978	9	45.9	12	51.6	5	59.4	12	45.7
1979	11	43.9	14	49.5	13	62.7	8	59.2
Total	73		62		62		74	
Weighted mean		39.5		49.4		62.1		44.5

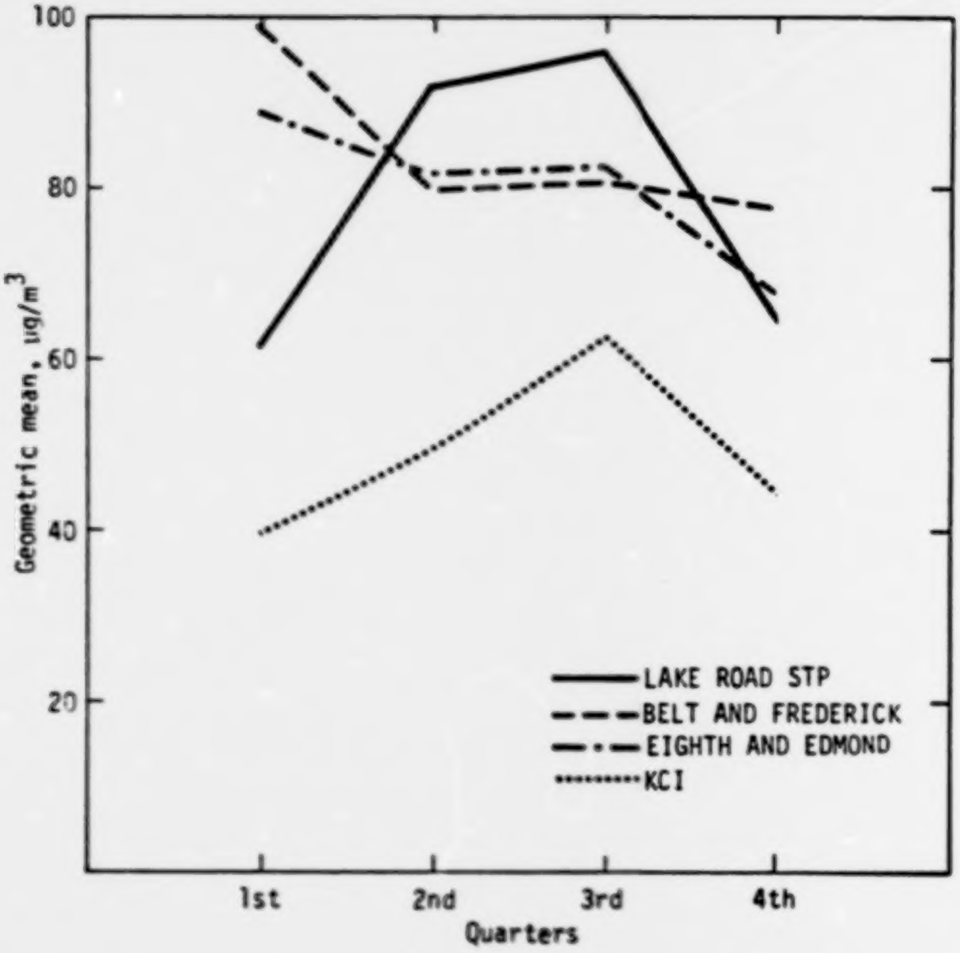


Figure 2. Seasonal patterns of TSP concentrations.

a high first quarter mean. This is probably a result of the resuspension of particles of salt and sand that have been placed on the streets during the winter months. The fourth quarter had the lowest mean in both areas.

The other two sites, Lake Road STP and KCI, differed in level of concentrations, but did exhibit similar curves. At these two sites, the low first quarter points indicate the reentrained dust from traffic is not a major factor. The increasing TSP levels through the second quarter and the third quarter peaks are typical in a rural environment. As agricultural activity increases through the spring into summer, TSP concentrations also increase. The third quarter peak also coincides with and reflects the dry weather that occurs during this time.

Weekday/Weekend and Daily Patterns--

Geometric means were again calculated for this technique; the data were categorized by day of the week rather than by quarter. Since sampling days are every sixth day, each day of the week should have approximately equal sample sizes. Examination of daily patterns sometimes facilitates identification of sources if the sources have a distinctive emission pattern. The bar charts in Figure 3 indicate the means and also the sample size for each day of the week at each site.

All three St. Joseph sites have a peak concentration on Tuesday. The Eighth and Edmond site's peak is not as predominant as the other two sites since Monday was also a relatively high concentration day. The Belt and Frederick and Lake Road STP sites both revealed Tuesdays with concentrations that were significantly higher than any other day of the week. (All statements of significance were verified at the 95 percent confidence level by a nonparametric test called the Scheffe procedure). This Tuesday phenomenon was not evident in the KCI TSP data. No explanation was found, but more specific point source data could be helpful.

At the Eighth and Edmond site there was no significant decrease in concentration levels on the weekends. Despite adequate sample size, the normal decrease in levels in a downtown area on weekends was not apparent. Examination of daily traffic counts revealed that traffic levels on Saturday are almost equal to weekday volumes because some of the downtown businesses remain open and because of the proximity to U.S. Highway 59. Sunday traffic volumes do decrease, however, to about 60 percent of weekday levels. The slight decline in Sunday concentrations does not indicate a high sensitivity to traffic volumes.

The last interpretation to be made from the weekday analysis was found at the Belt and Frederick site. A significant secondary peak is seen on Friday and Saturday. This is undoubtedly

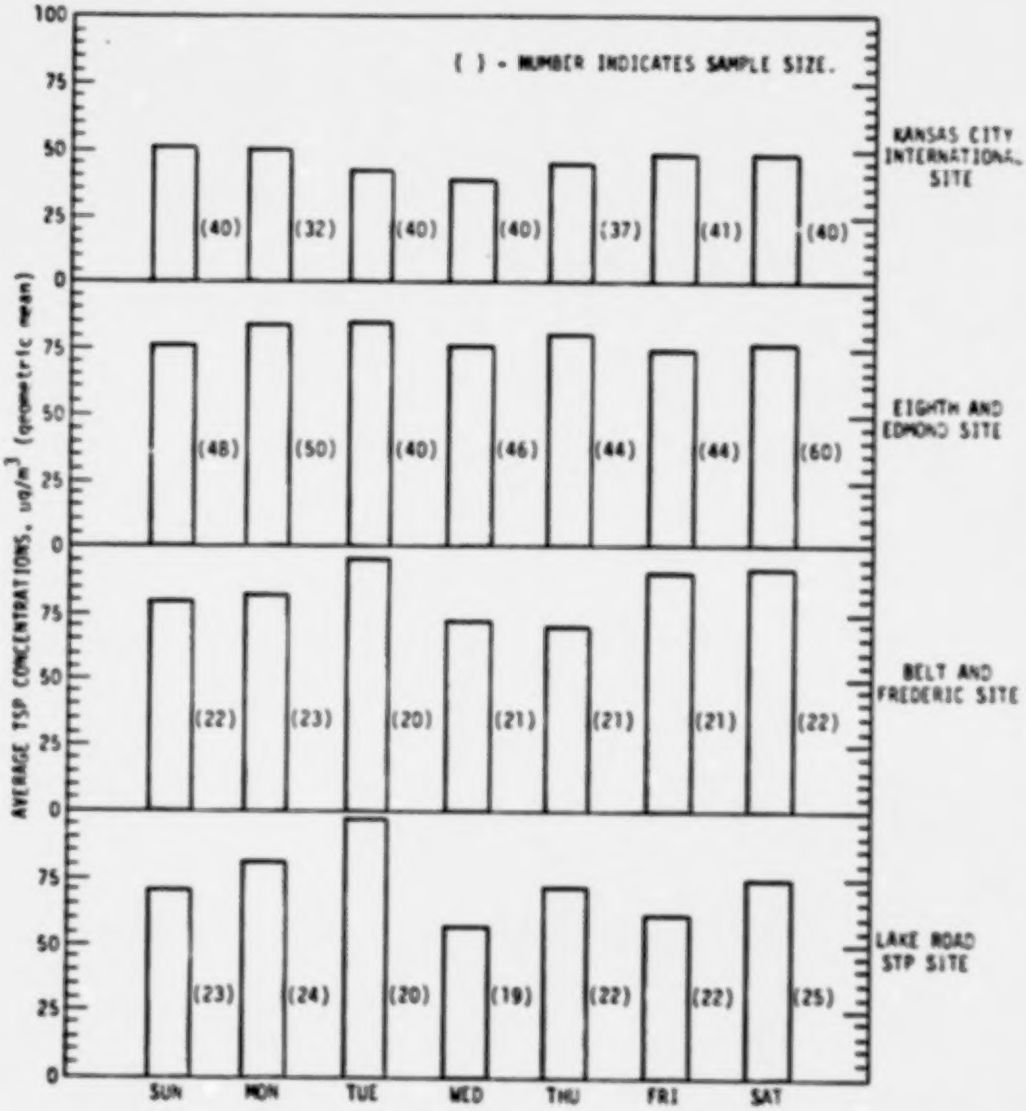


Figure 3. Daily patterns of TSP concentrations.

a result of increased traffic in the parking lots surrounding the shopping center where the monitoring site was located.

Intersite TSP Correlations--

In order to perform this analysis it was necessary to have an adequate number of samples from each of the four sites on the same sampling day. Correlation coefficients were then computed between daily TSP concentrations measured at one site and those measured on the same days at the other three sites. Two sites that are relatively close together (e.g., less than 2 miles apart) can be expected to correlate highly if they are being impacted by the same dominant source and windflow is not distorted.

The matrix shown below gives the correlation between the four sites being analyzed. These correlations were calculated from a data set of 32 samples.

	Eighth and Edmond	Lake Road STP	Belt and Frederick	KCI
Eighth and Edmond	1.0	0.37	0.92	0.55
Lake Road STP		1.0	0.30	0.55
Belt and Frederick			1.0	0.53
KCI				1.0

The only two sites that correlate highly are the Eighth and Edmond and Belt and Frederick sites. This should be expected since both of these sites are traffic-impacted urban sites. The correlations between the other sites were all quite low (≤0.55). This tends to indicate that the TSP problem is quite localized since the fluctuations in concentrations are not experienced simultaneously at the St. Joseph sites.

Pollution Roses--

A pollution rose relates TSP concentrations to wind direction and it can pinpoint the existence of a major source if the shape of the rose clearly points toward an identifiable source. To derive the pollution rose for each monitoring site, all sample days with a predominant wind direction were stratified into eight compass directions. For each of the eight directions, the percentage of days with TSP concentrations greater than 75 $\mu g/m^3$ (primary particulate standard) was calculated. The pollution roses are shown in Figures 4 through 6.

At the Eighth and Edmond site, violations occurred most frequently when winds were from the south or north. This may be due to the location of point sources in St. Joseph, which are predominantly located along a north-south axis. The Lake Road data (Figure 5) indicate that violations are most likely when winds are from directions ranging from 0 to 180 degrees. Several point and area sources are located in that direction. The Belt and Frederick pollution rose (Figure 6) shows more

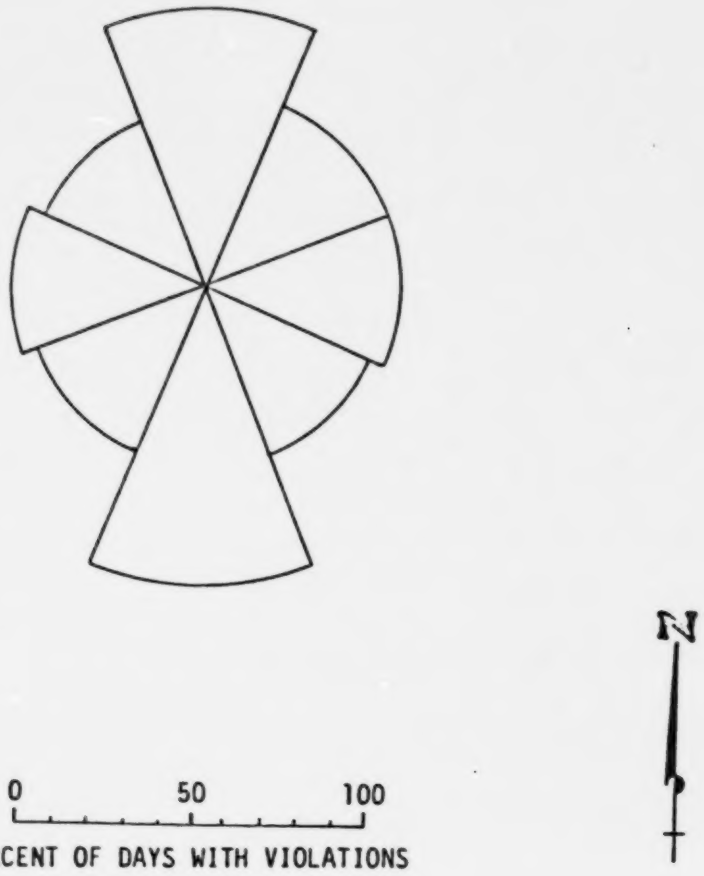


Figure 4. Pollution rose, Eighth and Edmond site.

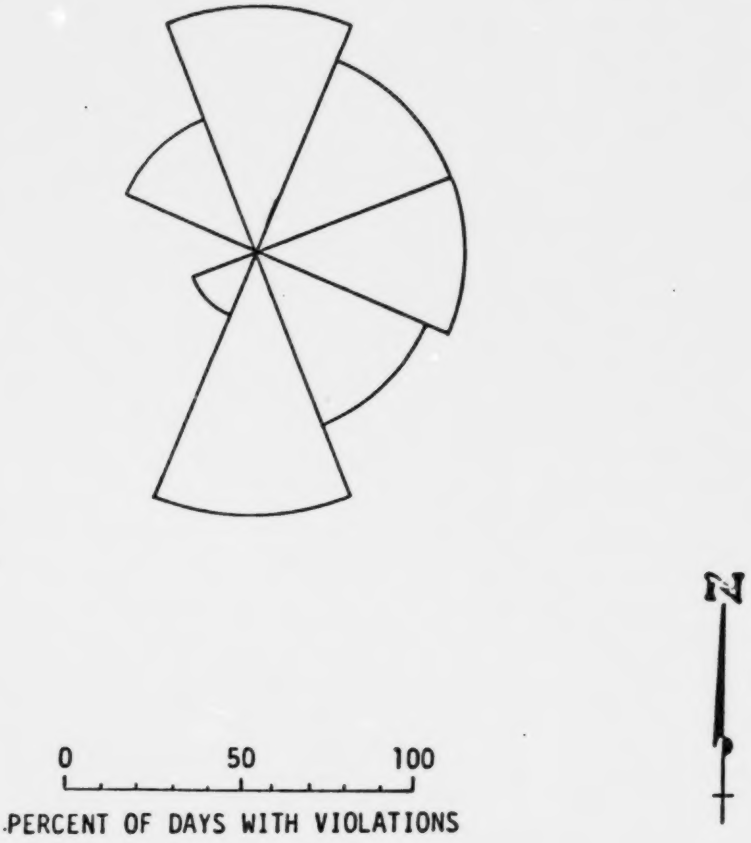


Figure 5. Pollution rose, Lake Road STP site.

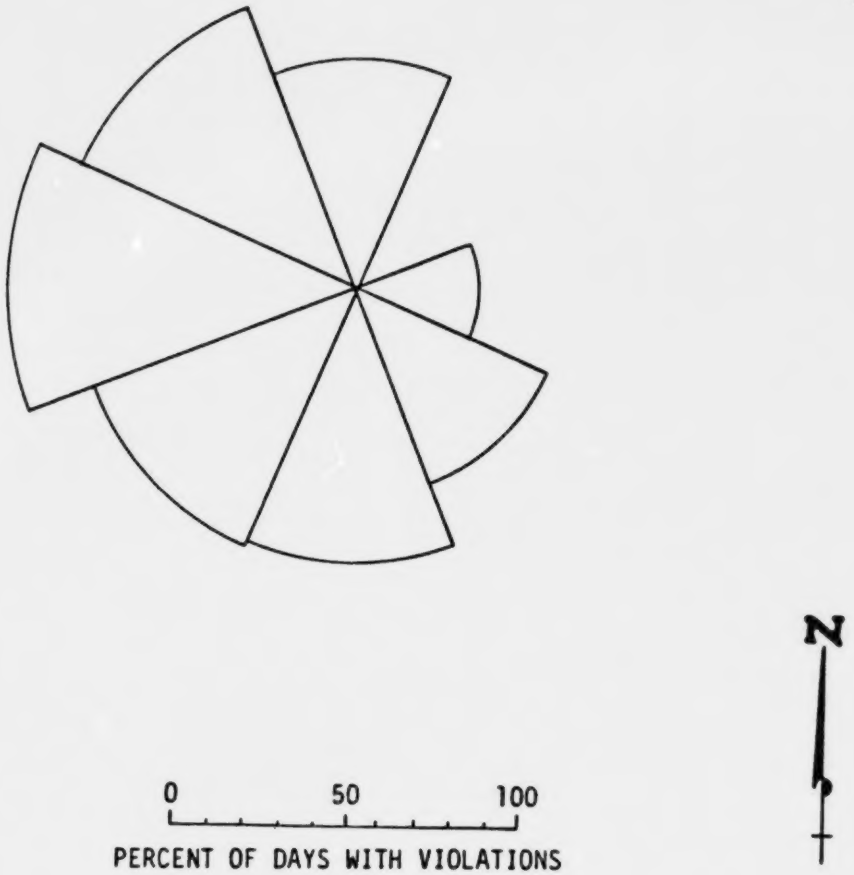


Figure 6. Pollution rose, Belt and Frederick site.

frequent violations when winds are from 180 to 360 degrees. This can be explained by the proximity of the two major streets west and north of the monitor and by the fact that the monitor is located east of most of the urbanized area of St. Joseph.

Concentration Roses--

A concentration rose is similar to a pollution rose except that it expresses the geometric mean concentration for each direction as opposed to the percentage of days with violations of the air quality standard. This information indicates the wind directions that impact the site most heavily and may also define influential point or area sources. The number of samples for each direction are also a problem in this analysis, and a larger data base would improve the confidence in results substantially.

Table 6 gives the mean concentrations and number of samples for each wind direction at each site. This information is shown graphically in Figure 7, where each concentration rose is drawn on a city map at its respective site. The location of major point sources in St. Joseph were also added to the map in order to assist with the explanation of results.

The Eighth and Edmond rose shows the greatest impact when winds are from the south and southwest. The Lake Road STP is influenced when winds are from the east and northeast. This would indicate that the industrial region between these two sites is a major contributor to the problem at these locations. The Belt and Frederick rose indicates that the strongest impact comes when winds blow across both highways toward the monitor. The southwest arm points toward the point sources and urbanized area but is possibly exaggerated since the sample size for that direction was small. The fact that all three roses point towards the point sources and the urbanized area tends to discredit the theory that high concentrations are an extra-regional problem solely caused by rural fugitive dust or long-range transport.

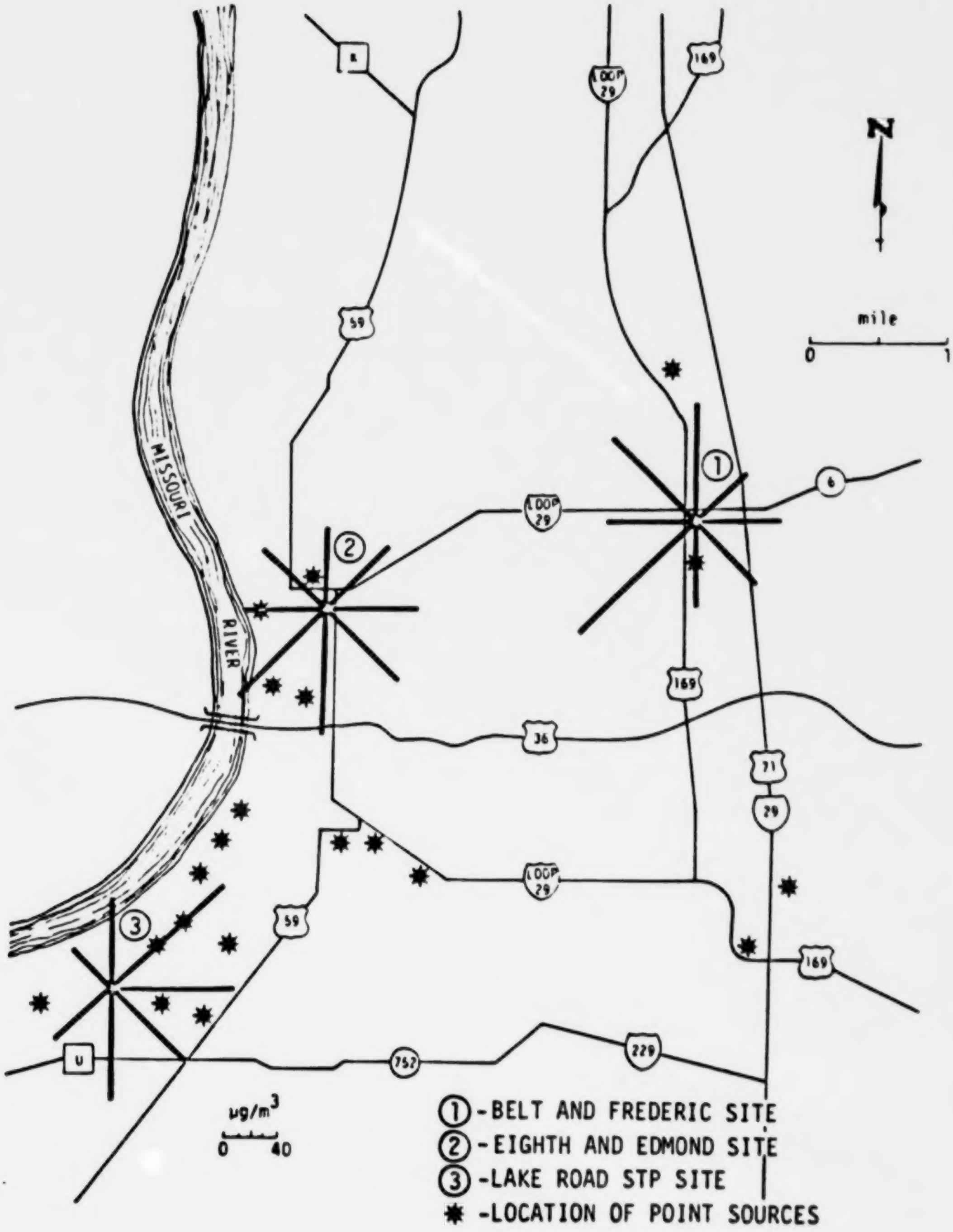
Correlation and Regression Techniques (Meteorological Variables)--

A detailed discussion of multiple linear regression (MLR) can be found in various statistical references.[2,3] Multiple linear regression was used to attempt to provide a ranking of meteorological variables in order of the variance each explained in TSP concentrations. The variables that were used were windspeed, wind direction, 24-hour precipitation total, and number of days since >0.01 in. rain. These variables were selected because they were found to be significant in similar analyses performed elsewhere.

Multiple linear regression was first run on data from the Eighth and Edmond site since it had the largest data set. The amount of variance explained by all four variables was less than 1 percent. No definite conclusion can be drawn from this finding. It may indicate that meteorological variables are not

TABLE 6. MEAN TSP CONCENTRATIONS BY WIND DIRECTION

	Eighth and Edmond	Lake Road Sewage Treatment Plant	Belt and Frederick	Kansas City International Airport
North				
No. of samples	39	11	12	15
TSP, μg/m^3	68	75	97	43
Northeast				
No. of samples	8	5	3	10
TSP, μg/m^3	74	124	58	35
East				
No. of samples	16	5	4	7
TSP, μg/m^3	62	101	71	59
Southeast				
No. of samples	30	15	14	27
TSP, μg/m^3	67	85	73	60
South				
No. of samples	81	36	42	54
TSP, μg/m^3	102	92	70	54
Southwest				
No. of samples	8	6	4	10
TSP, μg/m^3	97	62	130	50
West				
No. of samples	10	4	6	9
TSP, μg/m^3	61	24	72	29
Northwest				
No. of samples	65	17	20	38
TSP, μg/m^3	69	43	96	44


N
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MISSOURI
RIVER
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LOOP 29
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59
6
36
71
29
U
752
229
①
②
③
μg/m^3
0
40
① -BELT AND FREDERIC SITE
② -EIGHTH AND EDMOND SITE
③ -LAKE ROAD STP SITE
✱ -LOCATION OF POINT SOURCES

Figure 7. Concentration roses.

significant factors in TSP concentrations, but it may also indicate that only the forms of the meteorological variables were not significant. Multiple linear regression was not run for the remaining sites because of these poor results and smaller sample sizes at the other sites.

A simple correlation of TSP and the four meteorological variables was also performed. As could be expected, the correlation coefficients between TSP and meteorological variables were poor. The highest correlation was between TSP and days since rain at 0.13. A correlation of quarterly TSP and DSR showed a higher but still weak relationship.

Analysis of Precipitation--

Since precipitation was found in other studies to be an important factor in explaining variations in TSP concentrations, additional analyses were performed on some precipitation variables. The additional analyses selected were trend analyses of quarterly TSP means plotted against quarterly precipitation totals and daily TSP concentrations versus days since rain.

The quarterly TSP and precipitation graph should ideally define a line with negative slope. As precipitation increased for the quarter, the mean TSP concentration should decrease. Unfortunately, the data compiled (see Tables 2 through 5 and Table 7) did not exhibit any definite line. The plot of the data points was too scattered to explain any expected relationship between TSP and precipitation.

The analysis of TSP concentrations versus DSR revealed a more normal result than did any of the other precipitation analyses. The TSP data were divided into six DSR groups, zero through five or more days. The geometric means of these six groups were then calculated and a line was plotted for each site. The graphs are shown in Figure 8. The lines obtained from these plottings were very similar to each other and to curves obtained in other studies. The day of precipitation, day zero, is as expected, the lowest. This is a result of surface wetting (which decreases fugitive emissions) and the washout of particulates from the atmosphere. On successive days, average concentrations increase. This increase is hypothesized to result from the gradual drying of the surfaces. This finding supports the influence of fugitive emissions, as opposed to point source emissions, on TSP concentrations in St. Joseph.

SUMMARY

A table summarizing the major findings of the statistical analysis is shown in Table 8. Study of seasonal patterns in the temporal analysis indicated two distinctive types of sites, urban and rural. These patterns could be logically explained by examination of sources close to the monitoring locations.

TABLE 7. ANNUAL AND QUARTERLY MEAN WINDSPEED AND PRECIPITATION TOTALS, 1974-1979

Year	First quarter		Second quarter		Third quarter		Fourth quarter		Annual	
	Wind-speed	Precip.	Wind-speed	Precip.	Wind-speed	Precip.	Wind-speed	Precip.	Wind-speed	Precip.
1974	10.1	3.35	11.2	15.17	9.1	7.24	10.4	10.36	10.2	36.12
1975	11.9	5.22	9.9	12.52	7.9	11.20	11.8	5.13	10.4	34.07
1976	12.9	3.72	10.8	13.87	9.1	2.94	9.9	3.15	10.7	23.68
1977	11.7	4.31	10.3	13.96	9.3	22.07	10.2	9.40	10.4	49.74
1978	10.0	3.48	11.1	12.98	8.9	12.19	10.8	5.31	10.2	33.96
1979	12.2	6.09	9.9	10.72	8.7	9.50	12.5	5.44	10.8	31.75
Arithmetic mean	11.5	4.4	10.5	13.2	8.8	10.9	10.9	6.5	10.5	34.9

Source: Kansas City International LCD.

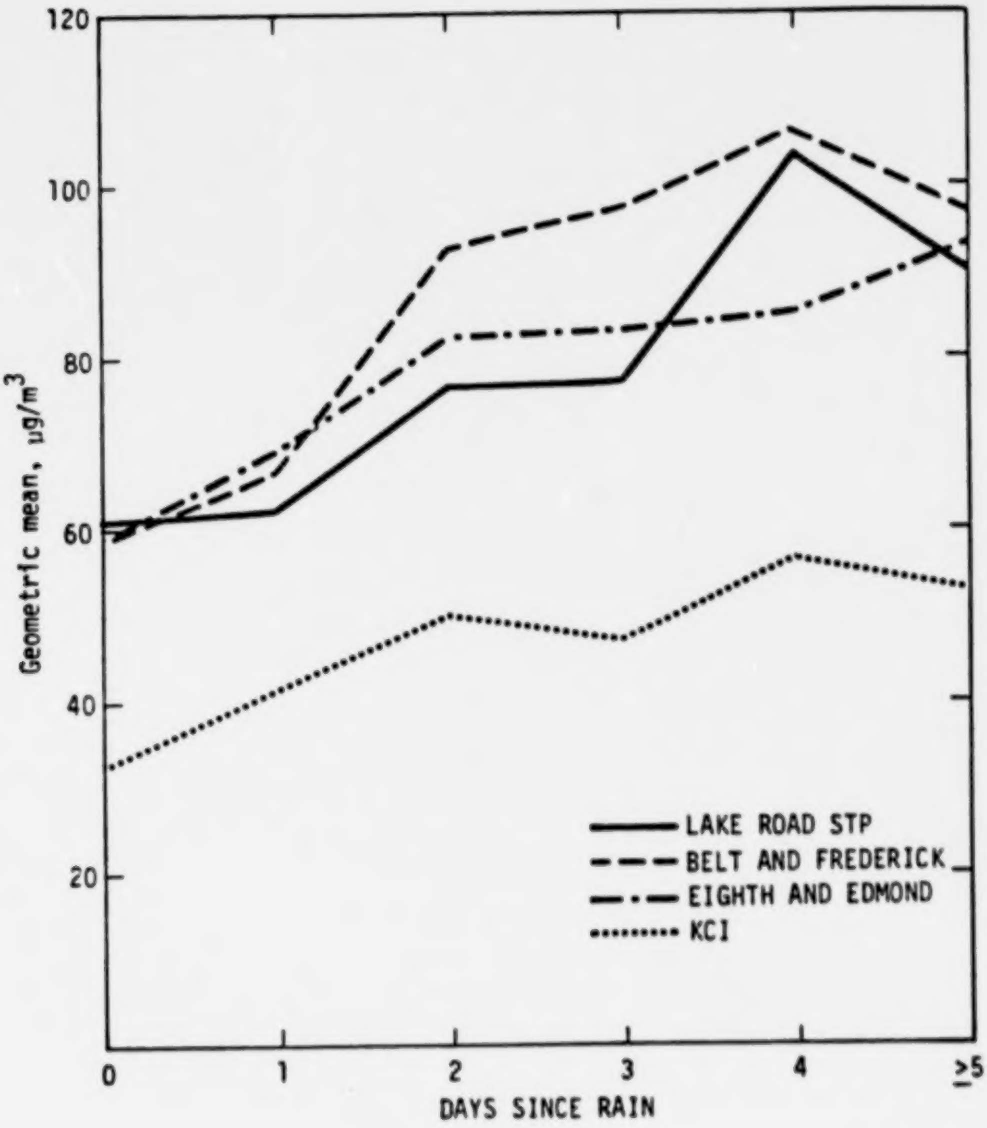


Figure 8. TSP concentrations versus days since rain.

TABLE 8. SUMMARY OF FINDINGS FROM STATISTICAL ANALYSES

Analysis	St. Joseph sites			Baseline site
	Eighth and Edmond	Lake Road Sewage Treatment Plant	Belt and Frederick	Kansas City International Airport
Seasonal patterns	Typical traffic impact, first quarter peak due to salt/sand operations.	Rural impact, third quarter peak result of agricultural activity.	Typical traffic impact, first quarter peak due to salt/sand operations.	Rural impact, third quarter peak result of agricultural activity.
Weekday/weekend and daily patterns	Tuesday peak, no weekend drop as expected.	Tuesday peak.	Tuesday peak, Fri-Sat. peak due to shopping center traffic.	No significant peaks, mid-week low.
Intersite TSP correlations	Correlation of 0.92 with Belt.	Poor correlation with all sites.	Correlation of 0.92 with Eighth.	Poor correlation with all sites.
Pollution roses	Violations most frequent with winds from the north or south.	Violations most likely with winds from 0-180°.	Violations most likely with winds from 180-560°.	Not analyzed.
Concentration roses	Urban influence suggested.	Urban influence suggested.	Urban influence suggested.	Concentrations highest with winds from east and southwest sectors.
Correlation and regression techniques	Inconclusive	Not analyzed.	Not analyzed.	Not analyzed.
TSP vs. days since rain	Normal curve through day four, only site to increase on day five.	Normal curve.	Normal curve.	Normal curve, low levels expected for background site.

Examination of daily patterns revealed significantly higher concentrations on Tuesday. This could not be explained with the information available. The intersite correlation of TSP levels was low with the exception of the Eighth and Edmond and Belt and Frederick sites. Pollution and concentration roses from the three St. Joseph sites all showed an influence from within the urban area. The meteorological variables examined produced inconclusive results.

In conclusion, the two questions proposed at the beginning of this section can be addressed. If high TSP concentrations in St. Joseph are caused solely by extra-regional sources, i.e., long-range transport and/or rural fugitive dust, all data from the four monitoring locations should show similar patterns. The three St. Joseph sites should show similar seasonal patterns, daily patterns, pollution and concentration roses, and intersite TSP correlations should be high. The similarity between St. Joseph sites does not exist. The two sites that did correlate well appeared to do so because of local traffic sources rather than extra-regional sources. In addition, because the KCI site is between Kansas City and St. Joseph and should receive the same rural fugitive dust influence as the St. Joseph sites, the patterns of KCI TSP concentrations should be similar to patterns of St. Joseph TSP concentrations. Examination of the historical TSP data did not show this similarity. In response to the first question, the data indicate that sources within the immediate St. Joseph area are primarily responsible for high observed TSP concentrations.

With regard to the second question, the specific sources within St. Joseph cannot be identified through this statistical analysis. General source categories, however, can be delineated. The pollution and concentration roses from the three sites all point towards the urbanized area. Within the urbanized area, the sources could be industrial sources or fugitive dust sources. At the Eighth and Edmond site and the Belt and Frederick site, reentrained dust from nearby streets appears to be a source of fugitive dust. At the Lake Road site, both industrial and fugitive sources probably contribute to high measured TSP concentrations.

REFERENCES

1. Digest of Ambient Particulate Analysis and Assessment Methods. PEDCo Environmental, Inc., Kansas City, Missouri. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. September 1978.

2. Experimental Statistics, Ordinance Engineering Design Handbook, ORDP 20-110. June 1962.

3. Workbook-Demonstration Studies for Control of Nontraditional Particulate Sources. Draft. PEDCo Environmental, Inc., Kansas City, Missouri. October 1979.

SECTION 3

MICROINVENTORY RESULTS AND APPLICATION OF THE EMPIRICAL MODEL TO MONITORING SITES

The Environmental Protection Agency (EPA) has recently developed an empirical model to relate particulate emissions in an area to ambient air quality. The particulate emission data are obtained through a survey technique referred to as a microinventory. The empirical model can be used to determine the impact of a source or source category on ambient air quality, to predict air quality at locations where there is no sampler, and to evaluate the impact of particulate control measures.

Microinventories were performed at the following locations:

1. Lake Road Sewage Treatment Plant
2. Rosecrans Memorial Airport
3. Eighth and Edmond Streets--Post Office
4. 3458 Ashland--Fire Station
5. Faraon Street Sewage Treatment Plant

The first and third sites have been operating since 1976 and 1973, respectively; data from these two sites were included in the statistical analysis in Section 2. The fourth and fifth sites are monitoring locations that began operation in 1980. The Rosecrans Airport site is a planned site.

METHODOLOGY

Microinventory

The survey procedure employed at the five sites in St. Joseph was to ground survey all probable sources of particulate emissions within a 1-mile radius of each of the five sampling sites. Point and area sources of particulate emissions were located on maps during the ground survey, and the maps were labeled with pertinent data such as size and boundaries, observed activity and operational characteristics, and estimated emission rates. Two observers independently estimated and agreed upon parameters observed at each source to increase accuracy and completeness. The exact procedures followed in the microinventory are described in Appendix A.

Point Sources--

During the ground survey, an attempt was made to locate every significant particulate point source. Once identified, annual particulate emissions from industrial sources were obtained from a point source listing or an engineering knowledge of the processes involved. Further, any source listed in the point source file and not identified in the survey was located by using universal transverse mercator (UTM) coordinates and street addresses.

A table of point sources within 5 miles of the monitor was compiled for each sampler site. Only those sources with estimated annual particulate emissions of 25 tons/yr or more were considered to be point sources. Smaller sources listed in the point source file were considered only if they were located within 1 mile of the sampler. The emissions from these smaller sources were combined with the industrial process area source category.

Distance and compass direction from the monitoring site were computed for each point source with emissions greater than 25 tons/yr, so the source could be assigned to the appropriate wind quadrant.

Area Sources--

The area to be microinventoried was divided into three zones as shown in Figure 9. All identified fugitive dust sources within the survey area were recorded on the data sheet by zone with estimates of size, location, and activity. Appropriate emission factors were then applied to each source to calculate estimated annual emissions. These emission factors are discussed in Appendix B. The individual emission factors used for each source category are listed in Table 9.

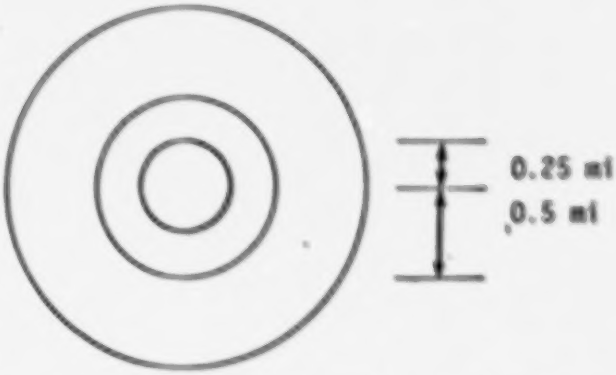


Figure 9. Area source zones in 1-mile radius.

TABLE 9. EMISSION FACTORS FOR MICROINVENTORIES

Source category	Emission factor for St. Joseph	Units
Railroad yards	0.1	ton/acre per year
Reentrained dust		
clean paved streets	3.9	g/VMT[a]
commercial streets	16.9	g/VMT
Exhaust		
clean streets	0.69	g/VMT
commerical streets	1.2	g/VMT
Unpaved roads	2.8	lb/VMT
Cleared or exposed areas	0.11	ton/acre per year
Construction	0.33	ton/acre per year Residential-3 mos Industrial-6 mos
Agriculture		
corn	0.03	ton/acre per year
soybeans	0.06	ton/acre per year
milo	0.02	ton/acre per year
Unpaved parking lots/alleys	1.4	lb/VMT
Unpaved storage areas	0.2	ton/acre per year
Grain elevators	1.8	tons/silo per year
Cattle feedlots	3.0	tons/acre per year
Incinerator	7.0	lb/ton of refuse burned

[a] Vehicle mile traveled.

Conventional area source emissions are not accounted for in the survey and were added to the above emissions in order to determine total area source particulate emissions by sector. The categories of conventional area sources included incinerators and small (<25 tons) point sources. Residential and commercial fuel combustion emissions were not included because of lack of data.

Emissions for two other sources, vehicle exhaust and reentrained dust from streets, were calculated for each zone based on the vehicle miles traveled (VMT) in each zone. These VMT data were calculated from 1978 traffic volume maps obtained from the Missouri State Highway Department.

Empirical Model

The empirical model is a multiple linear regression equation with the annual geometric mean particulate concentration as the dependent variable and with four independent variables. The model was derived from microinventory data from 79 sites in four cities (Kansas City, St. Louis, Portland, and Birmingham) and yielded a multiple correlation of 0.89 with the four independent variables. The model is more fully described in Appendix C.

SITE SUMMARIES

A five-page summary was compiled for each sampling site inventoried in the St. Joseph nonattainment area. These site data summaries are presented in this subsection.

The first page of each summary is a complete description of the individual site including SAROAD code (if applicable), street address, UTM coordinates, location and height of the monitor, topography in the vicinity of the site, localized sources within 200 ft of the monitor, and historical air quality data. The sampling site location and surrounding 1-mile radius survey areas are illustrated on the second page. Two photographs illustrating the sampler are presented on the third page of the summary. A listing of all the point sources located within a 5-mile radius of the sampler is included on the fourth page. The listing is limited to those sources emitting greater than 25 tons/yr. Each source is designated by number. Point sources within 1 mile are located on the map of the survey area. The fifth page summarizes the area source emissions for a 1-mile radius about the sampler site.

DESCRIPTION OF SITE

SAROAD code - 26 4260 008

Location - Lake Road Sewage Treatment Plant, Lake Road, St. Joseph

UTM coordinates - 338.8, 4398.4

Monitor height - 4 ft, on ground

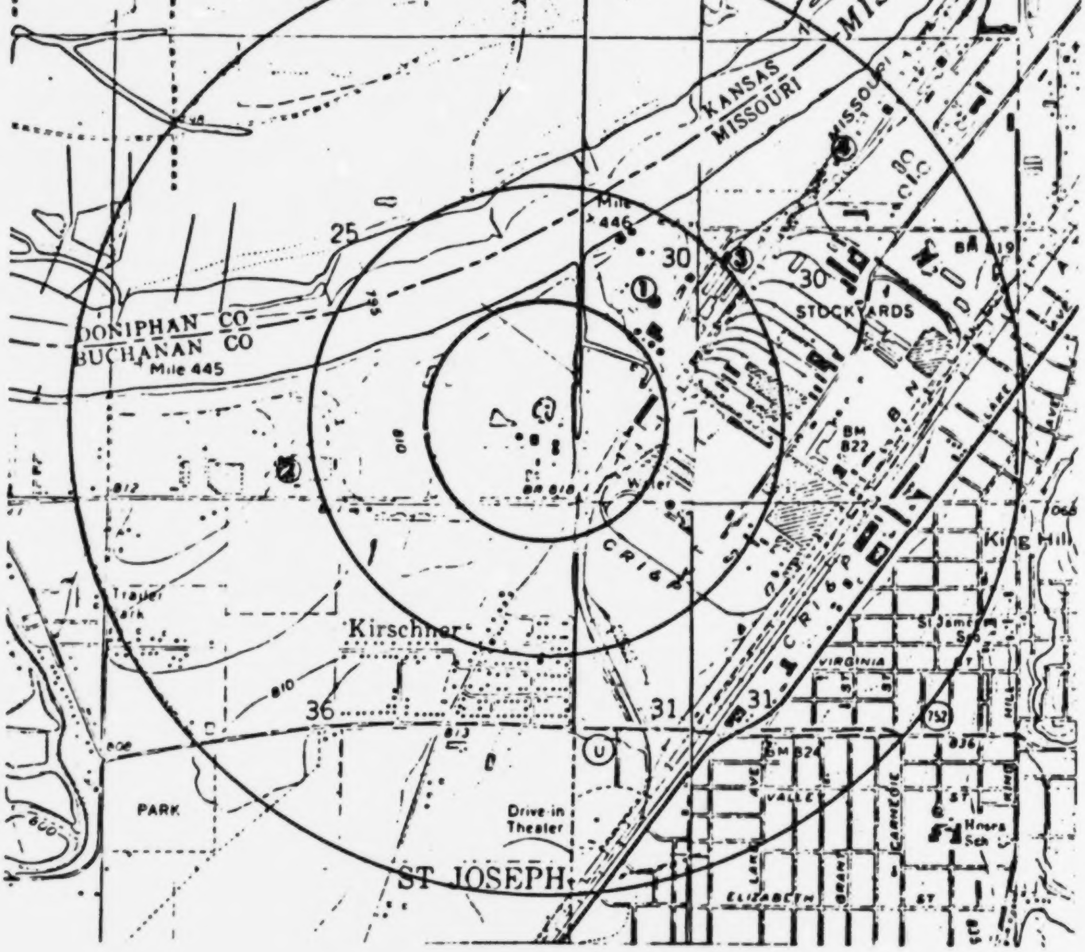
Topography - No special terrain

Localized sources, within 200 ft of monitor -

Source	Distance	Description
None		

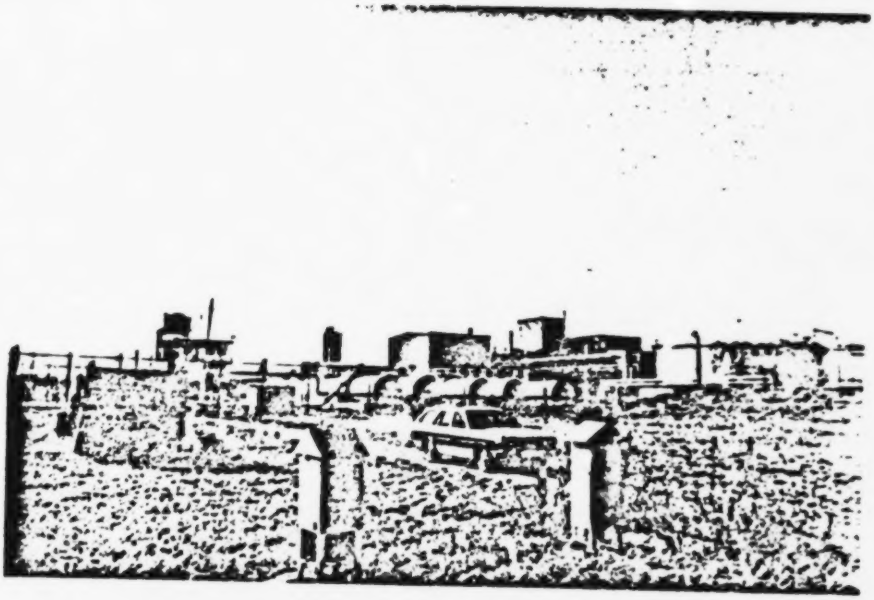
Air quality data -

Year	Annual geometric mean, µg/m³	No. of samples
1979	84	37
1978	79	44
1977	68	54
1976	94	21


19
24
25
30
30
31
31
36
MISSOURI
KANSAS
MISSOURI
Mile 447
Mile 446
Mile 445
DONIPHAN CO
BUCHANAN CO
STOCKYARDS
BM 822
King Hill
Kirschner
Trailer Park
VIRGINIA
BM 824
VALLEY
PARK
Drive-in Theater
ST JOSEPH
ELIZABETH

One-mile radius around Lake Road Sewage Treatment Plant site,
St. Joseph

Viewed to the northeast



Viewed to the southwest

Sampler at Lake Road Sewage Treatment Plant, St. Joseph

POINT SOURCE SUMMARY

Plant ID number	Plant name	Emission level, tons/yr	Distance from site, mi	Wind quadrant	UTM coordinates x	UTM coordinates y
1	St. Joseph Power & Light Lake Road Plant	565	0.3	1	339.2	4398.7
2	Carnation and Company Stockyard Station	34	0.5	4	338.0	4398.1
3	Farmland Soybean Processing	38	0.6	2	339.5	4399.0
4	Pillsbury Company "A" Elevator	150	0.9	2	339.9	4399.3
5	Quaker Oats	500	2.3	2	341.9	4400.4
6	Herzog Construction	41	2.5	2	342.6	4399.8
7	Ralston Purina	139	4.7	2	346.3	4398.6

AREA SOURCE SUMMARY

Site: Lake Road Sewage Treatment Plant, St. Joseph

Source category	Activity rate	Emissions by zone, tons/yr 1	2	3	Total
COMBUSTION:					
Incinerators	1			0.2	0.2
Air					
Auto exhaust	1.5×10^6 VMT	0.2	0.3	10.7	11.2
INDUS PROCESSES:					
Ind processes	4 sources	12.0		40.0	52.0
FUGITIVE DUST:					
Railroad yards	81 acres	0.5	0.6	7.0	8.1
Clean streets	15.5×10^6 VMT	1.0	0.4	64.0	65.4
Comm streets	1.3×10^5 VMT		0.5	0.1	0.6
Unpaved roads	6.3×10^4 VMT		17.4	76.1	93.5
Cleared areas	17 acres	0.5	1.0	0.4	1.8
Construction					
Agriculture	208 acres		2.8	6.2	9.0
Storage areas	30 acres	4.2	1.8		6.1
Unpaved pkg lots	28 acres	1.7	6.3	11.0	19.0
Cattle feedlots	16 acres			48.0	48.0

Recap	Emissions by zone, tons/yr			
	1	2	3	Total
COMBUSTION	0.2	0.3	10.9	11.4
IND PROCESSES	12.0		40.0	52.0
FUGITIVE DUST	7.9	30.8	212.8	251.5
Total	20.1	31.1	263.7	314.9

DESCRIPTION OF SITE

SAROAD code - None

Location - Rosecrans Memorial Airport, St. Joseph

UTM coordinates - 337.1, 4403.8

Monitor height - 25 ft, on roof of building below control tower

Topography - No special terrain

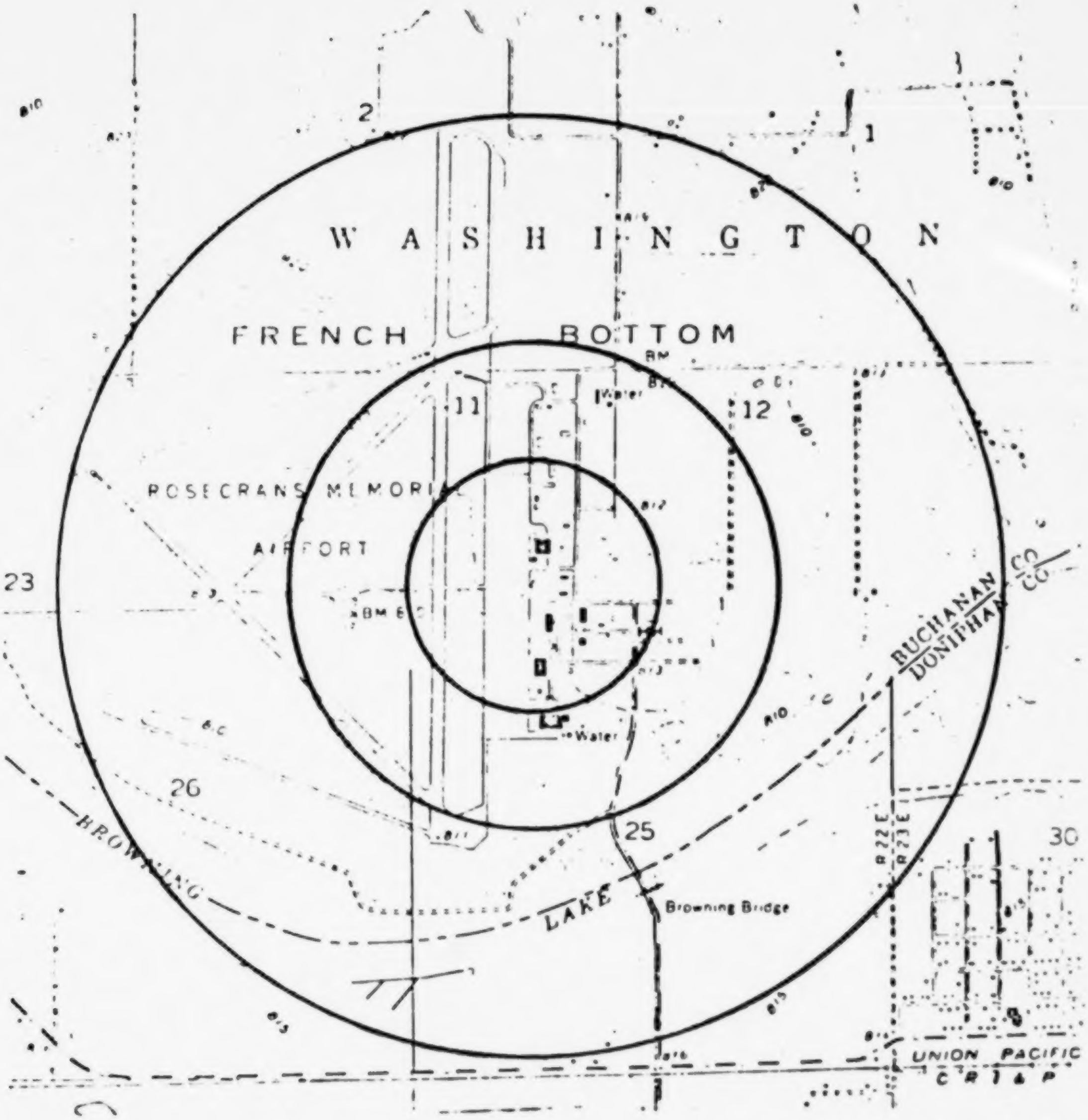
Localized sources, within 200 ft of monitor -

Source	Distance	Description
None		

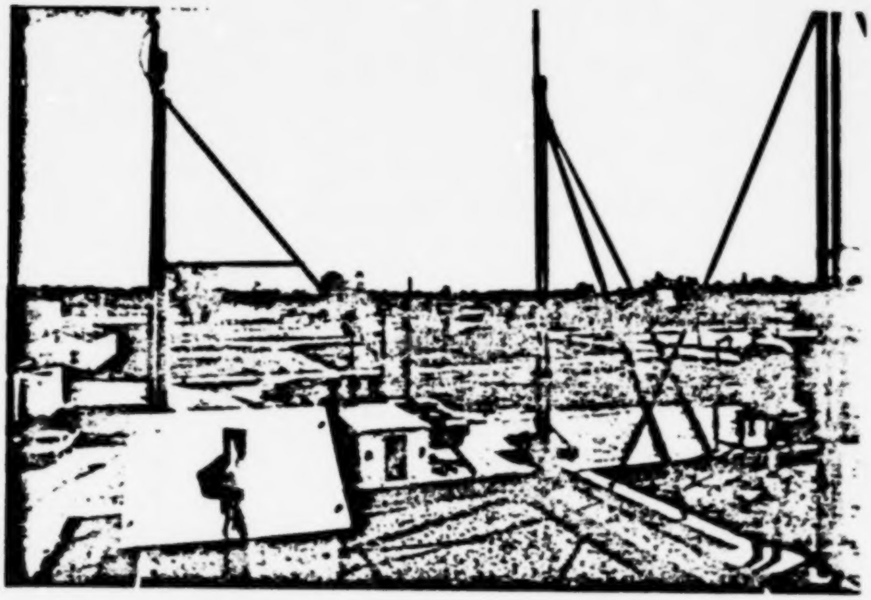
Air quality data -

Year	Annual geometric mean, $\mu g/m^3$	No. of samples
Not available		

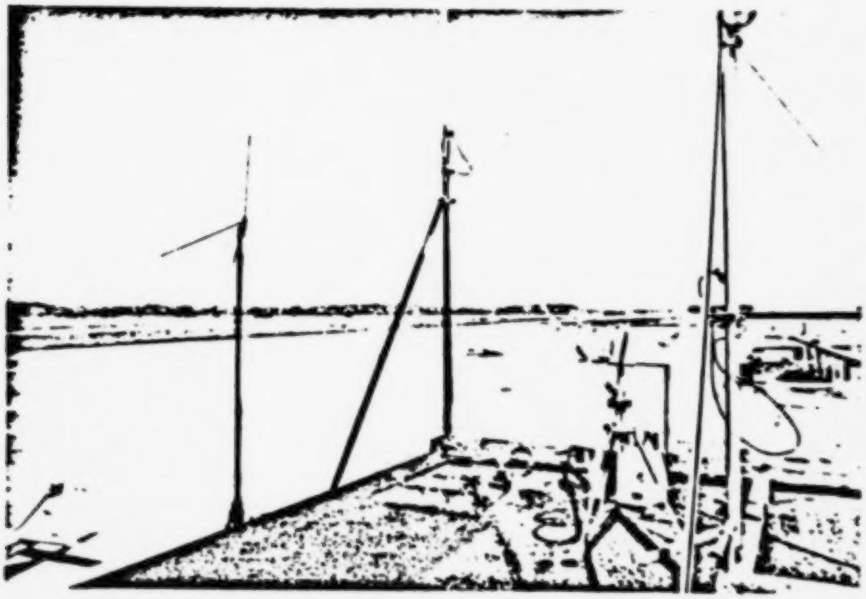
F


WASHINGTON
FRENCH BOTTOM
ROSECRANS MEMORIAL AIRPORT
BUCHANAN CO
DONIPHAN CO
BROWNING LAKE
Browning Bridge
Water
BM
UNION PACIFIC
C R I & P
R 22 E
R 23 E
2
1
11
12
23
26
25
30

One-mile radius around Rosecrans Memorial Airport site, St. Joseph



Viewed to the east



Viewed to the northwest

Sampler at Rosecrans Memorial Airport, St. Joseph

POINT SOURCE SUMMARY

Plant ID number	Plant name	Emission level, tons/yr	Distance from site, mi	Wind quadrant	UTM coordinates x	y
1	Pillsbury Company "A" Elevator	150	3.3	3	339.9	4399.3
2	Farmland Soybean Processing	38	3.3	3	339.5	4399.0
3	St. Joseph Power & Light Lake Road Plant	565	3.4	3	339.2	4398.7
4	Carnation and Company Stockyard Station	34	3.6	3	338.0	4398.1
5	Quaker Oats	500	3.7	2	341.9	4400.4
6	Herzog Construction	41	4.2	2	342.6	4399.8

AREA SOURCE SUMMARY

Site: Rosecrans Memorial Airport, St. Joseph

Source category	Activity rate	Emissions by zone, tons/yr 1	2	3	Total
COMBUSTION:					
Incinerators					
Air	100 LTD daily	1.2	2.3	1.2	4.7
Auto exhaust	2.1 x 10^6 VMT	0.3	0.9	0.2	1.4
INDUS PROCESSES:					
Ind processes					
FUGITIVE DUST:					
Railroad yards					
Clean streets	2.1 x 10^6 VMT	1.9	5.1	1.2	8.2
Comm streets					
Unpaved roads	3.0 x 10^4 VMT		3.5	38.4	41.9
Cleared areas					
Construction					
Agriculture	670 acres		1.1	29.7	30.8
Storage areas					
Unpaved pkg lots					
Cattle feedlots					

Recap	Emissions by zone, tons/yr			
	1	2	3	Total
COMBUSTION	1.5	3.2	1.4	6.1
IND PROCESSES				
FUGITIVE DUST	1.9	9.7	69.3	80.9
Total	3.4	12.9	70.7	87.0

DESCRIPTION OF SITE

SAROAD code - 26 4260 003

Location - Post Office, Eighth and Edmond Streets,
St. Joseph

UTM coordinates - 341.5, 4403.2

Monitor height - 40 ft, on roof of Post Office

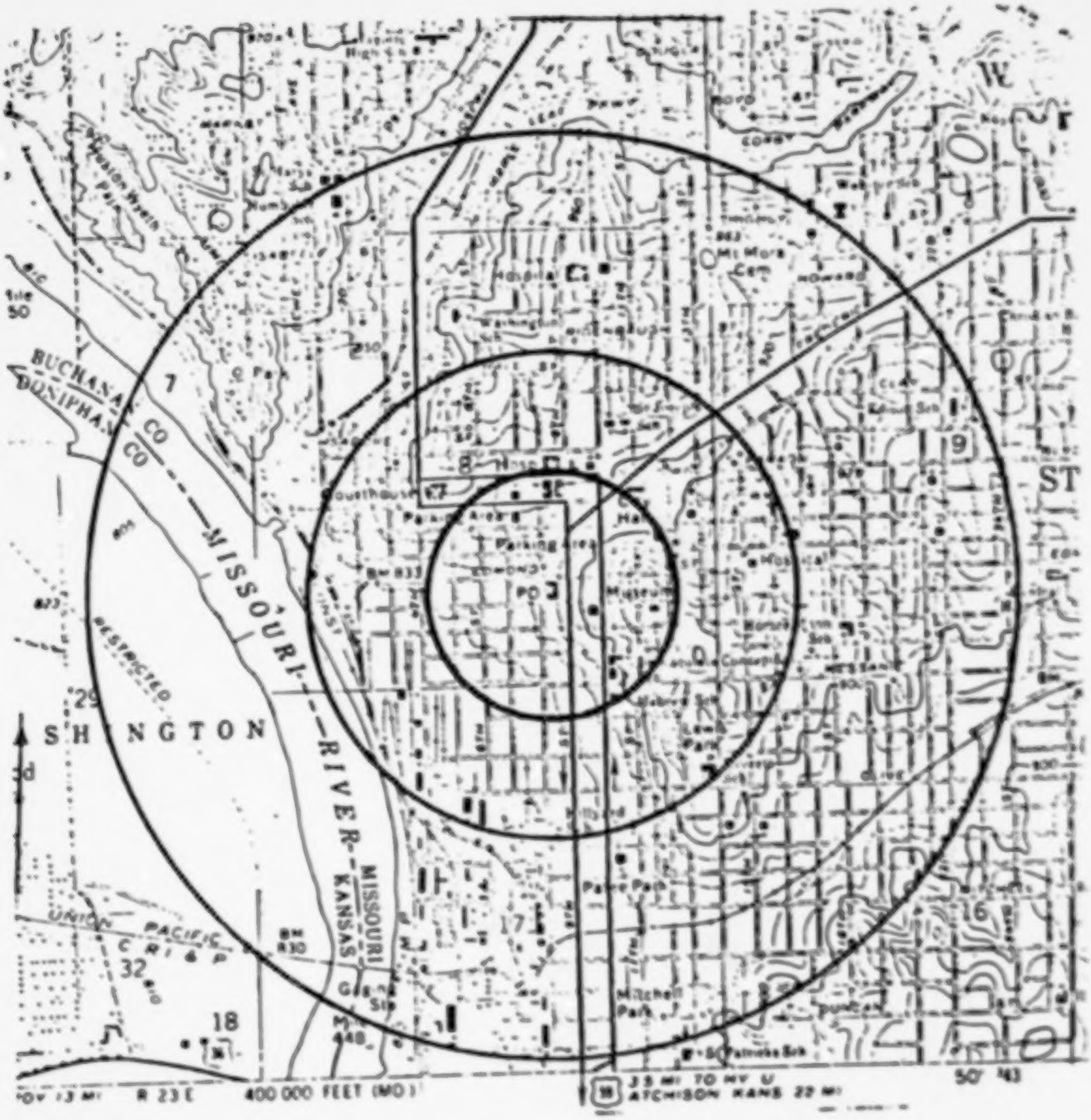
Topography - Elevated receptor

Localized sources, within 200 ft of monitor -

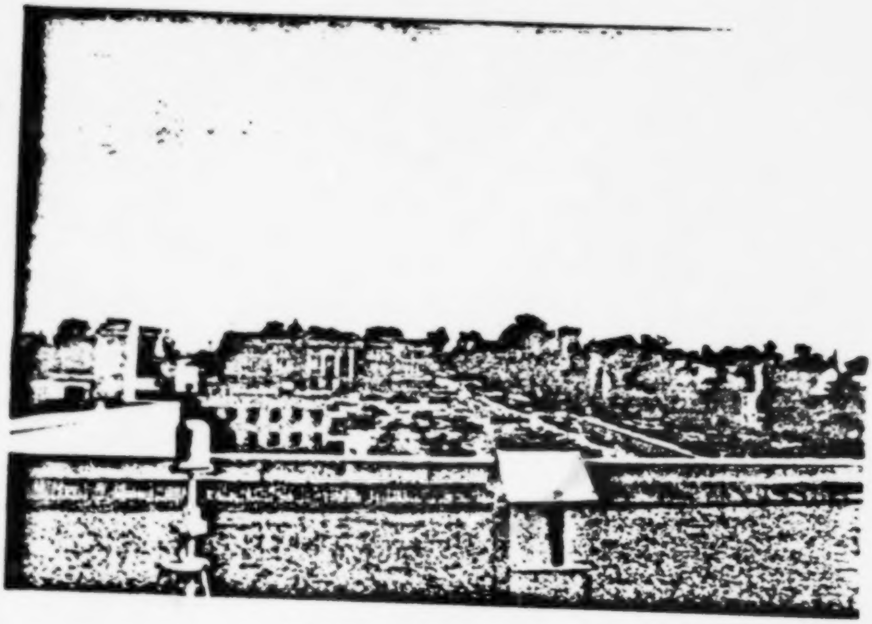
Source	Distance	Description
Eighth Street	45 ft	6000 ADT, clean, curbed
Charles Street	125 ft	2300 ADT, clean, curbed
Edmond Street	145 ft	5000 ADT, clean, curbed

Air quality data -

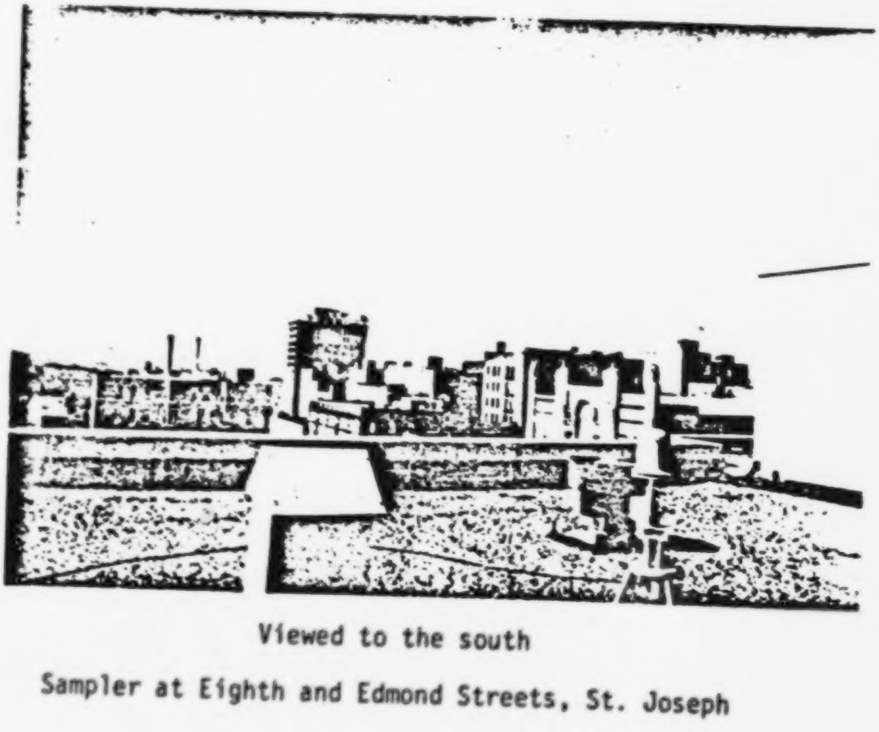
Year	Annual geometric mean, µg/m^3	No. of samples
1979	84	36
1978	95	43
1977	84	55
1976	82	61
1975	80	56
1974	71	56
1973	74	25


BUCHANAN CO
DONIPHAN CO
MISSOURI RIVER
MISSOURI
KANSAS
SHINGTON
UNION PACIFIC
C R I & P
Courthouse
Parking Area
Hospital
Mitchell Park
ST
400 000 FEET (MO)
R 23 E
ATCHISON KANS

One-mile radius around Eighth and Edmond Streets site, St. Joseph



Viewed to the north



Viewed to the south

Sampler at Eighth and Edmond Streets, St. Joseph

POINT SOURCE SUMMARY

Plant ID number	Plant name	Emission level, tons/yr	Distance from site, mi	Wind quadrant	UTM coordinates	
					x	y
1	Quaker Oats	500	1.8	3	341.9	4400.4
2	Herzog Construction	41	2.2	3	342.6	4399.8
3	Pillsbury Company "A" Elevator	150	2.6	3	339.9	4399.3
4	Farmland Soybean Processing	38	2.9	3	339.5	4399.0
5	St. Joseph Power & Light Lake Road Plant	565	3.1	3	339.2	4398.7
6	Carnation and Company Stockyard Station	34	3.8	3	338.0	4398.1
7	Ralston Purina	139	4.1	2	346.3	4398.6

AREA SOURCE SUMMARY

Site: Post Office, Eighth and Edmond, St. Joseph

Source category	Activity rate	Emissions by zone, tons/yr 1	2	3	Total
COMBUSTION:					
Incinerators	1		0.2		0.2
Air					
Auto exhaust	113.3 x 10^6 VMT	17.3	13.6	52.8	83.7
INDUS PROCESSES:					
Ind processes	4 sources	23.0	4.0	23.0	50.0
FUGITIVE DUST:					
Railroad yards	66 acres		0.1	5.8	5.9
Clean streets	106.4 x 10^6 VMT	97.8	32.3	295.1	425.2
Comm streets	6.9 x 10^6 VMT		7.9	0.6	8.5
Unpaved roads	7.2 x 10^4 VMT		3.5	46.7	50.2
Cleared areas	6 acres			0.7	0.7
Construction	21 acres		4.0	56.4	60.4
Agriculture					
Storage areas					
Unpaved pkg lots	13 acres		3.5	4.0	7.5
Cattle feedlots					

Recap	Emissions by zone, tons/yr			
	1	2	3	Total
COMBUSTION	17.3	13.8	52.8	83.9
IND PROCESSES	23.0	4.0	23.0	50.0
FUGITIVE DUST	97.8	51.3	409.3	558.4
Total	138.1	69.1	485.1	692.3

DESCRIPTION OF SITE

SAROAD code - 26 4260 006

Location - Fire Station No. 4, 3458 Ashland,
St. Joseph

UTM coordinates - 344.4, 4407.1

Monitor height - 15 ft, on roof of fire station

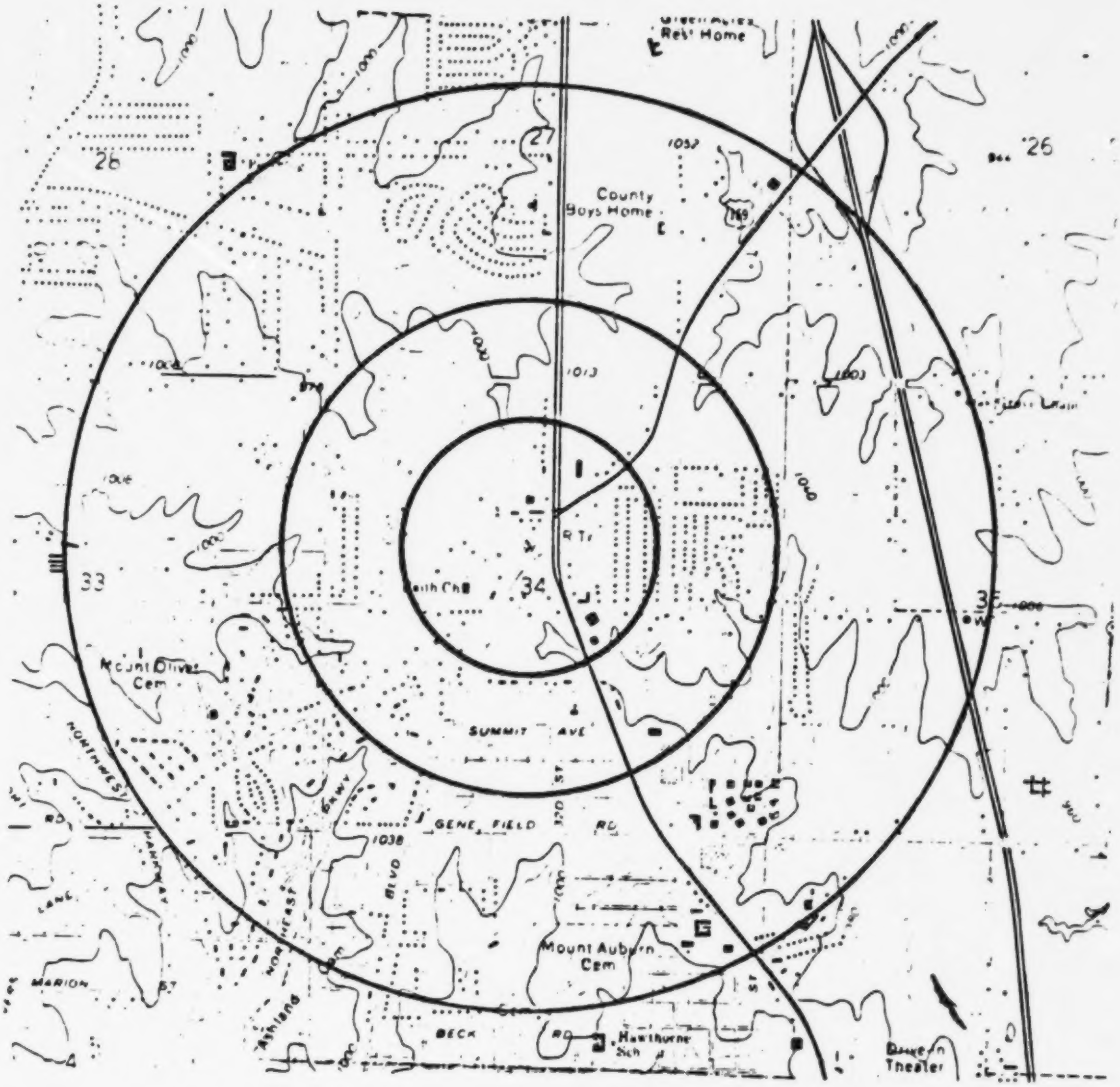
Topography - No special terrain

Localized sources, within 200 ft of monitor -

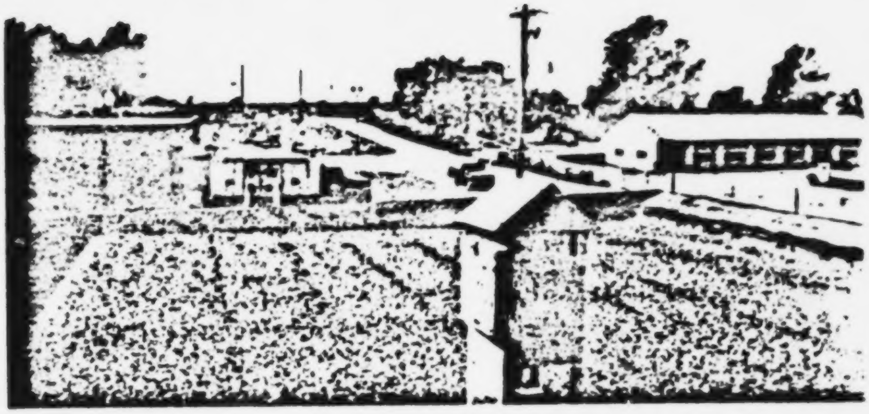
Source	Distance	Description
Lovers Lane	75 ft	8000 ADT, clean, curbed
Unnamed	40 ft	200 ADT, dirty, uncurbed

Air quality data -

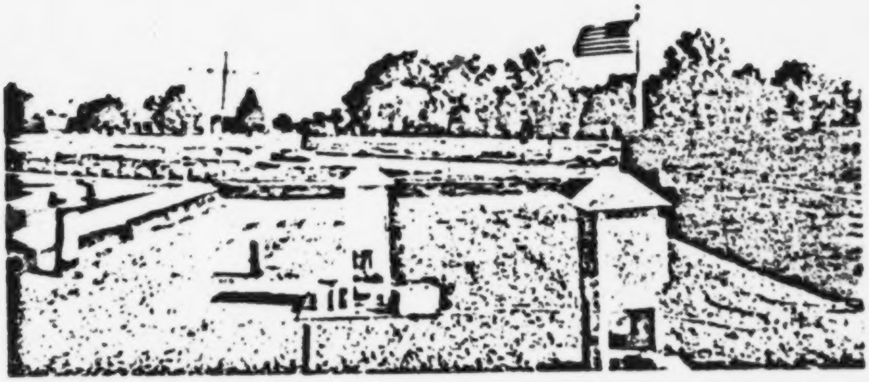
Year	Annual geometric mean, μg/m^3	No. of samples
Not available		


Green Acres Rest Home
26
27
1032
County Boys Home
26
1013
1003
33
Faith Ch
34
R Tr
35
Mount Olivet Cem
NORTHWEST
SUMMIT AVE
GENE FIELD RD
1038
BLVD
Ashland
MARION ST
Mount Auburn Cem
BECK RD
Hawthorne Sch
Drive-in Theater

One-mile radius around Fire Station No. 4 site, St. Joseph



Viewed to the west



Viewed to the east

Sampler at Fire Station No. 4, St. Joseph

POINT SOURCE SUMMARY

Plant ID number	Plant name	Emission level, tons/yr	Distance from site, mi	Wind quadrant	UTM coordinates x	UTM coordinates y
1	Quaker Oats	500	4.4	3	341.9	4400.4
2	Herzog Construction	41	4.7	3	342.6	4399.8

AREA SOURCE SUMMARY

Site: Fire Station No. 4, St. Joseph

Source category	Activity rate	Emissions by zone, tons/yr 1	2	3	Total
COMBUSTION:					
Incinerators					
Air					
Auto exhaust	35.9 x 10^6 VMT	4.2	4.9	16.3	25.4
INDUS PROCESSES:					
Ind processes	1 source			1.0	1.0
FUGITIVE DUST:					
Railroad yards					
Clean streets	35.9 x 10^6 VMT	23.9	27.5	92.1	143.5
Comm streets					
Unpaved roads	1.7 x 10^4 VMT	0.9		23.2	24.1
Cleared areas	1 acre	0.1			0.1
Construction	13 acres	2.0	9.9	1.0	12.9
Agriculture	51 acres		0.2	1.2	1.4
Storage areas					
Unpaved pkg lots					
Cattle feedlots					

Recap	Emissions by zone, tons/yr			
	1	2	3	Total
COMBUSTION	4.2	4.9	16.3	25.4
IND PROCESSES			1.0	1.0
FUGITIVE DUST	26.9	37.6	117.5	182.0
Total	31.1	42.5	134.8	208.4

DESCRIPTION OF SITE

SAROAD code - 26 4260 005

Location - Faraon Street Sewage Treatment Plant,
St. Joseph

UTM coordinates - 349.2, 4402.7

Monitor height - 25 ft, on roof of pumping station building

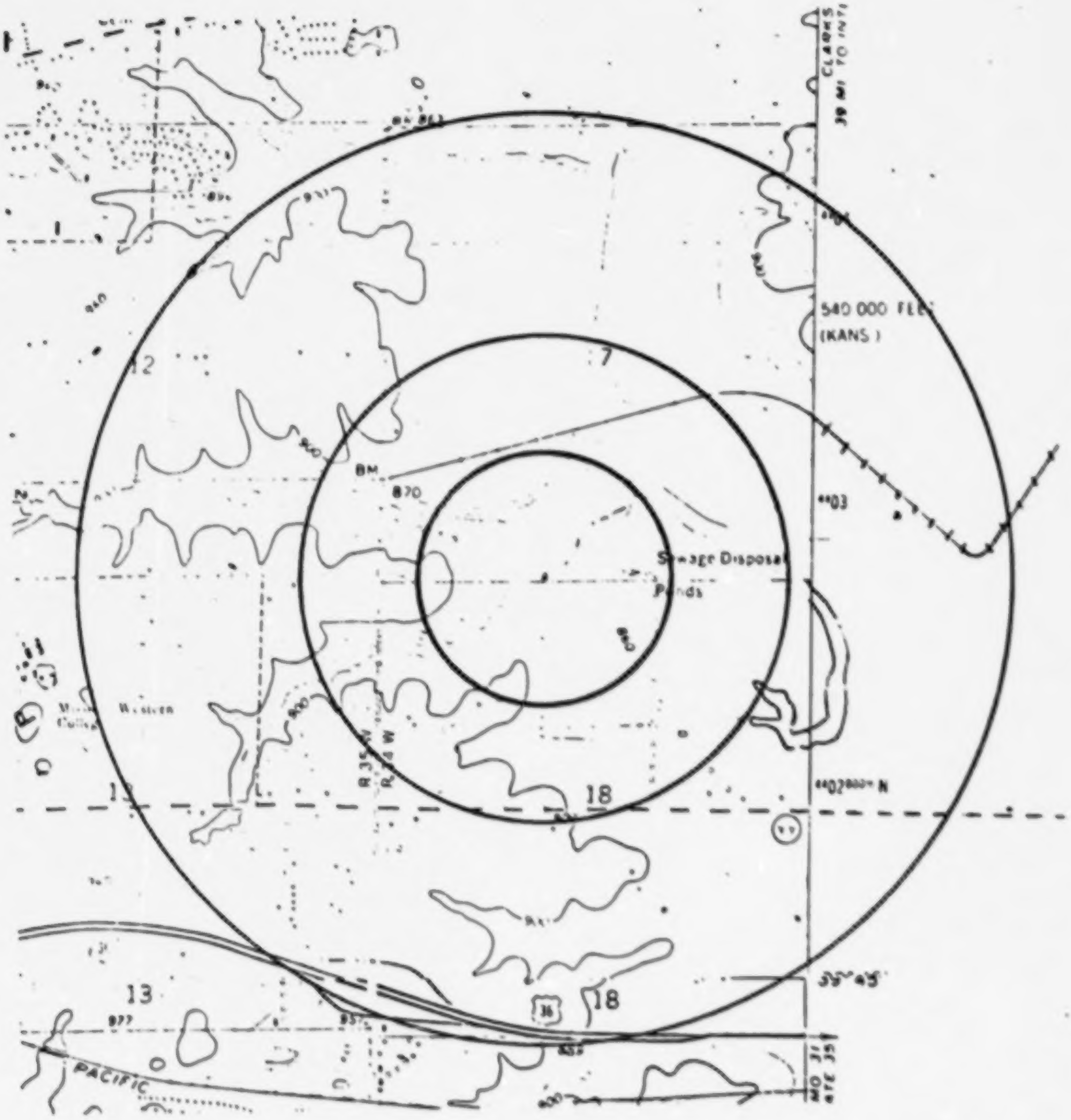
Topography - No special terrain

Localized sources, within 200 ft of monitor -

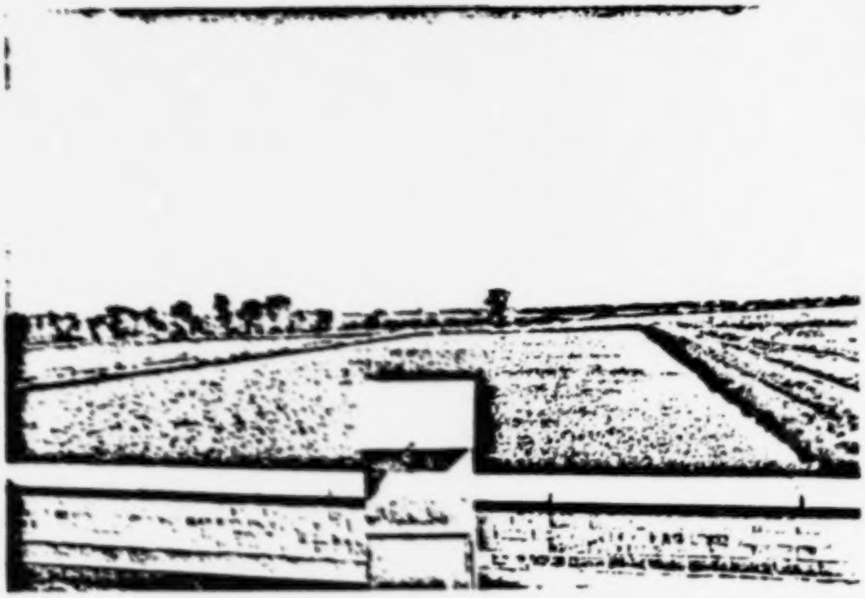
Source	Distance	Description
None		

Air quality data -

Year	Annual geometric mean, μg/m^3	No. of samples
Not available		


540 000 FEET
(KANS)
7
12
13
18
BM
870
Sewage Disposal
Ponds
R 35 W
R 34 W
PACIFIC
36

One-mile radius around Faraon Street Sewage Treatment Plant site,
St. Joseph



Viewed to the east

Viewed to the south

Sampler at Faraon Street Sewage Treatment Plant, St. Joseph

POINT SOURCE SUMMARY

Plant ID number	Plant name	Emission level, tons/yr	Distance from site, mi	Wind quadrant	UTM coordinates	
					x	y
1	Ralston Purina	139	3.1	3	346.3	4398.6
2	Herzog Construction	41	4.5	4	342.6	4399.8
3	Quaker Oats	500	4.8	4	341.9	4400.4

AREA SOURCE SUMMARY

Site: Faraon Street Sewage Treatment Plant, St. Joseph

Source category	Activity rate	Emissions by zone, tons/yr 1	2	3	Total
COMBUSTION:					
Incinerators					
Air					
Auto exhaust	1.3×10^6 VMT			0.9	0.9
INDUS PROCESSES:					
Ind processes					
FUGITIVE DUST:					
Railroad yards					
Clean streets	1.3×10^6 VMT			5.0	5.0
Comm streets					
Unpaved roads	4.4×10^4 VMT	2.3	14.0	44.6	60.9
Cleared areas					
Construction					
Agriculture	1609 acres	2.7	8.2	32.6	43.5
Storage areas					
Unpaved pkg lots					
Cattle feedlots					

Recap	Emissions by zone, tons/yr			
	1	2	3	Total
COMBUSTION			0.9	0.9
IND PROCESSES				
FUGITIVE DUST	5.0	22.2	82.2	109.4
Total	5.0	22.2	83.1	110.3

RESULT OF ANALYTICAL INVESTIGATIONS

Model Validation

The empirical model is in the form of a multiple linear equation; the annual geometric mean particulate concentration is the dependent variable, and four emission-related independent variables are quantified from the information presented in the previous subsection. Coefficients for the equation are as follows:

$$\begin{aligned} AVGAQ = {} & 0.00451(AREA) + 0.00096(POINT) + \\ & 50.5(LOCAL) + 18.6(VISDT) + 57.2 \end{aligned}$$

The constant term of 57.2 μg/m^3, background plus unexplained, includes a background value of 43 μg/m^3. This means that an impact of 14 μg/m^3 is not defined at each site. Much of this undefined portion may be from the same point source and area source categories shown in Table 14 (p. 4-5). Other possible sources include locally generated secondary particulates (sulfates and nitrates), condensed organics, and area sources beyond the 1-mile radius used in the microinventories. The background value, 43 μg/m^3, was based on data measured at Kansas City International Airport. The long-term average concentration is 48 μg/m^3. Since this monitor is probably affected by nearby sources, it was assumed that about 5 μg/m^3 of the concentration is due to these sources. The background concentration used in previous analyses of the Kansas City area was 38 μg/m^3. Consequently, a case could be made for almost any value between 38 and 48 μg/m^3 for the background concentrations in St. Joseph. It was felt that a 43 μg/m^3 background concentration would represent a reasonable value for the purposes of this study.

Based on the site data presented previously, predicted geometric mean concentrations were computed from the model. These data are compared with measured concentrations in Table 13 (p. 4-4). An average of 1978-1979 measured air quality data was used for this comparison. The data used to generate the emissions estimates ranged in age from 1973 data, for some of the point sources, to the 1980 field data from the microinventories. Consequently, it was felt that an average of 1978 and 1979 measured air quality data would be a more representative value for comparison with the model results than any individual year's data.

As shown in Table 10, measured air quality data were available at only two of the five sites. Consequently, the accuracy of the model cannot be evaluated for the other three sites. At the two sites with measured data, the model-predicted concentrations are within 3 percent of the measured data.

TABLE 10. EMPIRICAL PARTICULATE MODEL RESULTS

Site	Avg. 1978-1979 meas. conc, μg/m³	Model predicted conc, μg/m³
Lake Road Sewage Treatment Plant	81	83
Rosecrans Memorial Airport		59
Eighth and Edmond	90	88
Fire Station No. 4		79
Faraon Street Sewage Treatment Plant		59

A standard error of 13.6 μg/m³ was calculated from the original multiple regression model. Both of the model predictions are well within the error margins. Because the model has predicted within the error margins, it is assumed that relative contributions from the different variables are accurate for all of the sites.

Results

Contributions from the different components of the empirical model at each of the five sites are presented in Table 11. The largest source contribution to the model predicted concentration at all five sites is the background plus undefined component. At the Lake Road Sewage Treatment Plant, area sources were the next largest component (20.2 μg/m³), with an additional 6 μg/m³ concentration from point sources. At the Rosecrans Memorial Airport site, the background plus unexplained component accounts for almost all of the concentration. The Eighth and Edmond site is impacted by area sources and local sources almost equally with a slight contribution from point sources. The Fire Station site is not influenced by point sources, but is influenced by both area and local particulate sources. The Faraon Street sites concentration is almost totally composed of the background plus undefined component.

The contribution of individual source categories to the AREA component was further delineated and appears in Table 12. Of the AREA source component, reentrained dust is the largest source category at the Eighth and Edmond site and the Fire Station No. 4 site. At the Lake Road Sewage Treatment Plant, about 53.1 percent of the AREA source contribution was from industrial processes. The small AREA source component at the Rosecrans site was from a variety of sources. At the Faraon Street site, the small AREA source component was from unpaved roads and agriculture.

TABLE 11. CONTRIBUTIONS FROM DIFFERENT COMPONENTS OF THE EMPIRICAL PARTICULATE MODEL AT EACH OF THE SAMPLER SITES

Site	Contribution, $\mu g/m^3$				Model predicted conc., $\mu g/m^3$	Contribution, %			
	AREA	POINT	LOCAL	Background + undefined		AREA	POINT	LOCAL	Background + undefined
Lake Road Sewage Treatment Plant	20.2	6.0		57.2	83	24.2	7.2		68.6
Rosecrans Memorial Airport	1.4			57.2	59	1.7			97.6
Eighth and Edmond	17.5	0.2	13.2	57.2	88	19.9	0.2	15.0	64.9
Fire Station No. 4	9.4		12.2	57.2	79	11.9		15.5	72.6
Faraon Street Sewage Treatment Plant	1.9			57.2	59	3.2			96.8

TABLE 12. CONTRIBUTIONS OF INDIVIDUAL SOURCE CATEGORIES TO THE AREA SOURCE EMISSIONS AT EACH SAMPLER SITE
(percent)

Source category	Lake Road STP	Rosecrans	Eighth and Edmond	Fire Station No. 4	Faraon Street STP
Aircraft		17.4			
Incinerators	0.1		neg		
Auto exhaust	1.1	5.4	13.0	13.1	0.3
Industrial processes	53.1		13.0	neg	
Railroad yards	2.4		0.3		
Reentrained dust	6.6	30.7	67.4	74.3	1.9
Unpaved roads	5.2	28.1	2.5	4.1	54.0
Cleared areas	2.1		neg	0.3	
Construction			3.0	7.9	
Agricultural	0.6	18.4		0.2	43.8
Storage areas	18.3				
Unpaved parking lots	8.7		0.7		
Cattle feedlot	1.8				
Total percent	100.0	100.0	99.9	99.9	100.0
AREA, μg/m³	20.2	1.4	17.5	9.4	1.9

STP = Sewage treatment plant.

SECTION 4

SHORT-TERM PARTICULATE SAMPLING

PURPOSE

The primary purpose of the short-term sampling was to collect 24-hour TSP samples that were available immediately for chemical and microscopic analyses. To this end, five high-volume samplers were placed at the four existing St. Joseph sites (collocated with network samplers) and a proposed fifth site. These five sites were the same at which microinventories were performed (see Section 3):

1. Lake Road Sewage Treatment Plant

2. Rosecrans Memorial Airport

3. Eighth and Edmond Streets--Post Office

4. 3458 Ashland--Fire Station No. 4

5. Faraon Street Sewage Treatment Plant

The locations of these sites are shown in Figure 10.

Samples were taken every sixth day from September 12, 1980, to November 6, 1980. This schedule was identical to EPA's State and Local Air Monitoring (SLAMS) schedule at the existing sites and resulted in a total of 10 sampling days.

There were two secondary purposes for PEDCo obtaining special samples rather than simply using those generated by the existing network samplers after they had been weighed: one was a quality control check to ensure that high measured concentrations in St. Joseph were actual rather than due to a sampling bias; and the other was to obtain some concurrent data on particle size distribution. In conjunction with the latter purpose, dichotomous samplers were located at the Airport and Eighth and Edmond sites.

Dichotomous samplers provide data on two size fractions--inhalable particulate (IP, <15 μm) and respirable particulate (RP, <2.5 μm). These samplers were not specified in EPA's task order for this study, but PEDCo recommended their inclusion to

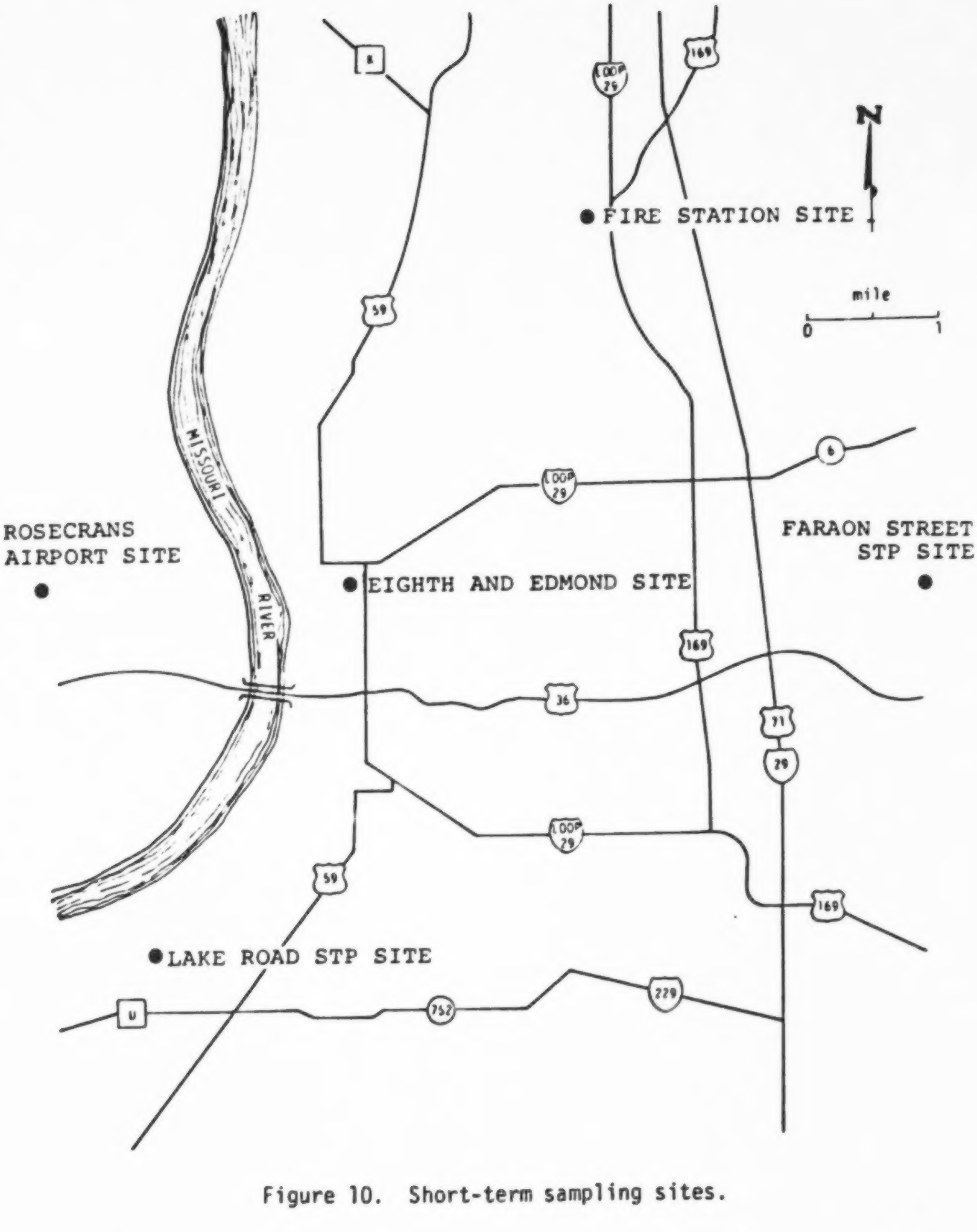

K
LOOP 29
169
N
FIRE STATION SITE
mile
0
1
59
MISSOURI
6
LOOP 29
ROSECRANS AIRPORT SITE
FARAON STREET STP SITE
EIGHTH AND EDMOND SITE
RIVER
169
36
71
29
LOOP 29
59
169
LAKE ROAD STP SITE
U
752
229

Figure 10. Short-term sampling sites.

obtain some definitive particle size data for the particulate analysis. Also, EPA may soon propose an inhalable particulate standard and this preliminary information, limited as it is, would provide an indication of the city's air quality for the newly-designated pollutant.

PRESENTATION OF RESULTS

Table 13 shows TSP concentrations measured by the special samplers and network samplers during the 10 sampling days. Overall, there were 49 valid special samples collected out of 50 scheduled samples.

The size fraction data obtained from the dichotomous samplers are shown in Table 14. Dichotomous samples were collected on only nine days because the equipment was not installed in time to coincide with the first TSP sampling day.

Meteorological data for the 10 sampling days are presented in Table 15.

INTERPRETATION OF RESULTS

The primary purpose of the short-term sampling (collection of TSP samples for chemical and microscopic analysis) was satisfied without difficulty.

Interpretation of data from the small data sets generated by the short-term sampling must be done with caution, especially since the information was all obtained in one season of the year. These samples were collected in a period straddling the third and fourth quarters. The previously described statistical analysis of historical TSP data from St. Joseph indicates that concentrations were highest during the third quarter; therefore, the special samples may have higher than annual average concentrations.

With the above qualification, it is noted that concentrations measured at the two sites with a long history of monitoring agreed well with their long-term averages:

Site	Geom mean of 10 samples, $\mu g/m^3$	Four-yr geom mean, $\mu g/m^3$
Lake Road	91	81
Eighth and Edmond	88	85

Two of the three "new" sites had concentrations equal to or exceeding the primary TSP standard during the short-term sampling. If these high short-term concentrations are good

TABLE 13. SHORT-TERM TSP CONCENTRATION DATA

Date	TSP concentration, $\mu g/m^3$					
	1 Lake Road	2 Rosecrans Airport	3 Eighth and Edmond	4 Fire Station	5 Faraon Street	Geometric mean
9-12	a	70	107	130	81	94
9-18	134[b]	83[b]	47[b] (101)	99[b]	54[b]	77
9-24	102 (115)	124	114 (121)	98	61	97
9-30	84[b] (94)	83[b]	102[b] (103)	73[b]	35	71
10-06	156	146[b]	147[b] (156)	139	118[b] (134)	141
10-12	129	126	120 (152)	112	157[b]	128
10-18	58[b] (33)	46	53[b] (100)	40[b] (42)	36 (64)	46
10-24	26 (28)	21	37 (47)	29 (31)	28 (23)	28
10-30	80	58	125 (129)	47 (59)	72 (58)	72
11-05	153 (132)	126	106 (114)	75 (77)	66	100
Geometric mean	91	77	88	75	62	78

[a] No data, sampler did not run.
[b] Filters selected for chemical and microscopic analyses.
Note: Numbers in parentheses indicate values from SLAM network samplers.

TABLE 14. DICHOTOMOUS SAMPLER DATA

	Rosecrans Airport				Eighth and Edmond			
	Concentration, μg/m³		Ratio		Concentration, μg/m³		Ratio	
Date	<2.5 μm	<15 μm	<2.5 μm/ TSP	<15 μm/ TSP	<2.5 μm	<15 μm	<2.5 μm/ TSP	<15 μm/ TSP
9-18	31	88	0.37	1.06	17	43	0.36	0.91
9-24	20	60	0.16	0.48	13	a	0.11	a
9-30	2	31	0.02	0.37	11	59	0.11	0.58
10-06	12	65	0.08	0.44	16	97	0.11	0.66
10-12	6	44	0.05	0.35	11	76	0.09	0.63
10-18	2	18	0.04	0.39	3	20	0.06	0.38
10-24	3	7	0.14	0.33	4	18	0.11	0.49
10-30	9	28	0.16	0.48	19	87	0.15	0.70
11-05	12	49	0.10	0.39	11	92	0.10	0.87
Geometric mean	7	35			10	52		
Average			0.12	0.48			0.13	0.65

[a] Filter voided.

TABLE 15. METEOROLOGICAL DATA FROM SPECIAL STUDY

Date	Kansas City International Airport data				Rosecrans Airport data	
	Prevailing wind direction	Mean wind-speed, mph	Days since rain, >0.01, in.	24-h total of last rain. in.	Prevailing wind direction	Mean wind-speed, mph
9-12 Fri	190° - S	15.5	11	1.04	190° - S	10.5
9-18 Thur	190° - S	8.2	2	0.38	180° - S	5.6
9-24 Wed	40° - NE	4.9	0	0.04	none	3.4
9-30 Tue	none	5.6	6	0.04	270° - W	5.3
10-06 Mon	220° - SW	11.4	12	0.04	240° - WSW	7.2
10-12 Sun	none	5.8	18	0.04	140° - SE	6.0
10-18 Sat	320° - NW	7.6	2	0.97	330° - NNW	9.7
10-24 Fri	300° - WNW	12.6	0	0.05	320° - NW	12.1
10-30 Thu	200° - SSW	11.2	2	0.03	210° - SSW	7.6
11-05 Wed	70° - ENE	3.6	8	0.03	180° - S	4.1

estimates of annual averages, the TSP nonattainment problem encompasses a much larger area of St. Joseph than presently projected.

The short-term samplers recorded concentrations that were lower than those recorded by the existing network samplers. This discrepancy could be the result of differences in procedures used for sampling and filter handling. The PEDCo data does agree with the State's monitoring information which indicates that the St. Joseph area is in nonattainment of the particulate NAAQS.

Particle size data obtained with the dichotomous samples were typical of those reported from other regional air quality studies. Inhalable particulate averaged 65 percent of TSP at the center city site (Eighth and Edmond) and 48 percent at the Airport site, which has low surrounding emission source density. The day-to-day variations in the IP/TSP ratio were also typical, with relative standard deviations of 0.18 and 0.22 at the two sites. Respirable particulate was 12 to 13 percent of TSP.

Respirable particulate has been found to be largely composed of secondary aerosols (sulfates, nitrates, organics) in previous studies. Sulfates alone have been reported to account for 40 to 50 percent of RP. For the seven samples that had both a chemical analysis of sulfates/nitrates and an RP measurement, the comparative readings were as follows:

Date	Site	SO_4 NO_3, % of TSP	RP, % of TSP
9/18/80	2	41	37
8/18/80	3	33	36
9/30/80	2	16	2
9/30/80	3	11	11
10/06/80	2	13	6
10/06/80	3	14	8
10/18/80	3	9	11

The correlation between the two particulate fractions was 0.91. Based on this very small data set, sulfates and nitrates were found to constitute the bulk of the sub-2.5 μm particles in St. Joseph, too.

SECTION 5

ANALYSIS OF SAMPLES BY MICROSCOPY

METHODOLOGY

Applicability of Techniques

Optical microscopy has been widely used in recent years to identify the probable origins of individual particles collected on filters. By classifying and estimating the size of a large number of particles on a filter, the relative contributions of different source categories can be estimated for that sample. The technique is also used to obtain size distribution information in the coarse particle size range (>1 to 2 μm).

The method is only semiquantitative for several reasons. First, it is not possible to manually count enough particles on a filter for the counted sample to be representative of the actual size distribution. Large particles have greatly disproportionate influence on the distribution by weight (relative weight is proportional to ratio of diameters cubed), and the large particles occur randomly in the microscopist's fields. Secondly, each sample represents a unique set of source contributions; it would be too expensive to analyze enough filters to approach the annual average source contributions described by an emission inventory/ modeling procedure. Therefore, reported percentage compositions should only be considered accurate within a factor of two.

Selection of Samples

The filters for microscopic analysis were selected from those generated at five sites in St. Joseph during the 2-month short-term sampling period (Section 4). The budget allowed a total of 16 filters to be analyzed. The rationale for selecting the 16 filters from the 49 valid hi-vol samples is described below.

1. An "average condition" filter from each site was desired. Filters for September 18, a weekday with winds from the south (prevailing wind direction), were chosen because the average of concentrations on that day was 83 μg/m^3, near the all-site average for the short-term study. Five filters.

2. For comparison with the filters above, a series of filters on a day with winds from another direction was sought. September 30, a weekday with winds from the west, was chosen. Four filters.

3. Filters from one weekend day were specified. There were only two weekend sampling days, and one was at the end of a protracted period (18 days) without rain. The other weekend day, October 18, was chosen. Prevailing winds were from the NNW on that day. Three filters.

4. A day with high winds and the possibility of large amounts of windblown dust from surrounding areas was desired. October 6 had average windspeed of 11.4 mph out of the WSW and 12 days since the most recent rainfall. Samples from this day had the highest TSP concentrations of the 10 sampling days. Four filters.

5. Provision was made to analyze any filters that appeared to have anomalous readings. The only sample submitted under this criterion was from site 5 on October 12. It had a concentration of 157 $\mu g/m^3$, the highest recorded during the special study, and was from the site with the lowest average concentration. One filter.

The 16 filters selected are listed in Table 16. Meteorological conditions on these sampling days were previously presented in Table 15.

Microscopic Analysis Procedures

The heart of the analytical technique to identify and determine relative amounts of various particle types was polarized light microscopy. Sections of each hi-vol filter sample were mounted on glass slides in pools of standard immersion oil (n_D = 1.515) under coverslips. The immersion oil rendered the glass fibers invisible, thereby allowing transmission of light and observation of particle types collected on the filter surface and throughout the filter depth. No dichotomous samples were analyzed microscopically; the Teflon filter media is opaque under the microscope and cannot be cleared with immersion oil.

Particles were identified from physical properties such as morphology, size, surface texture and color, and optical properties such as refractive index, birefringence, and degree of transparency, that were observed by polarized light. Trained observers can categorize particles into more than 100 types and can even distinguish subtle differences in properties that identify particles with the same chemical composition but different

TABLE 16. SAMPLES SELECTED FOR ANALYSIS

Sample date	Sample site	Location	TSP, μg/m^3	IP, μg/m^3	Prevailing wind direction
9/18/80	1	Lake Road STP	134		180°-S
9/18/80	2	Rosecrans Airport	83	88	180°-S
9/18/80	3	Eighth and Edmond	47	43	180°-S
9/18/80	4	Fire Station	99		180°-S
9/18/80	5	Faraon Street STP	54		180°-S
9/30/80	1	Lake Road STP	84		270°-W
9/30/80	2	Rosecrans Airport	83	31	270°-W
9/30/80	3	Eighth and Edmond	102	59	270°-W
9/30/80	4	Fire Station	73		270°-W
10/18/80	1	Lake Road STP	58		330°-NNW
10/18/80	3	Eighth and Edmond	53	20	330°-NNW
10/18/80	4	Fire Station	40		330°-NNW
10/06/80	2	Rosecrans Airport	146	65	240°-WSW
10/06/80	3	Eighth and Edmond	147	97	240°-WSW
10/06/80	5	Faraon Street STP	118		240°-WSW
10/12/80	5	Faraon Street STP	157		140°-SE

physical form and origin. The microscopists were also aided by atlases with photomicrographs of particles of known origin.

The polarized light microscopy was augmented by two chemical tests and an ashing analysis to better quantify components in the fine particle size range (<2 μm) that were difficult to quantify microscopically. Sulfate and nitrate concentrations were determined by ion chromatography, and the organic content was estimated by low-temperature ashing in a radio-frequency, activated oxygen plasma asher. The sulfate and nitrate values were converted to equivalent ammonium salt concentrations, then ratioed to the TSP concentration of the filter to determine the percent compositions for these two fractions. The weight loss in ashing was used as the base weight for assigning percentages to all ashable fractions observed on the filter, such as coal fragments, elemental carbon, partially combusted fragments, rubber fragments, and biological material. Nonashable components were ratioed to the remaining weight of sample (after ashing and subtraction of sulfates and nitrates) to determine their percentages. Also, some microscopic observations were made on the ashed filter section because obscuration by organic particles was eliminated.

The percents by weight were calculated from particle counts by the following method:

1. All particles of a given type were assigned diameters at the time of viewing.
2. The total volume of each particle type was calculated, assuming spherical particle shape.
3. The total mass of each particle type was calculated from the volume and an estimated density based on the composition of the particles.
4. Two subtotals were calculated--combustible and noncombustible particles--and percentages for each particle type were calculated by comparison with the appropriate subtotal.

The microscopic examination was also enhanced by the occasional use of X-ray diffraction (XRD) and scanning electron microscopy (SEM). These advanced techniques were used to gain additional information on prevalent particle types that could not be classified with assurance.

The microscopy work was done under subcontract by Illinois Institute of Technology Research Institute (IITRI), a group with nationally recognized expertise in microscopic analysis of aerosol samples. Their procedures are explained in greater detail in their report, included herein as Appendix D. IITRI was not provided with information on particulate sources in the vicinity of each site, as this might have biased their identification of particles. Because of budget constraints, "blind" replicate samples were not submitted to check the precision of their work.

RESULTS

The particle types observed in the St. Joseph samples and the mass mean diameters of each type are presented in Table 17. Some potential sources for these particle types are also shown in the table. A major shortcoming of microscopy is the inability to distinguish different sources for the mineral components, which constituted about 35 to 75 percent of the particulate samples.

The percentage compositions of the 16 samples as reported from the combination of microscopy and chemical analyses are shown in Table 18. As indicated at the beginning of this section, inherent errors in this analytical technique suggest presentation of data in a less detailed form. Therefore, the same data are summarized into five broader source categories in Table 19.

In general, the St. Joseph samples had a relatively low mineral content compared with other midwest and western urban area samples analyzed in the same manner. Minerals commonly account for 70 to 90 percent of sample weight. Therefore, it can be concluded early that the high measured particulate air pollution concentrations in St. Joseph are not strictly a result of windblown or reentrained soil dust.

The relatively low mineral percentages of necessity resulted in relatively high percentages for the other sample components--primary and secondary combustion products (including sulfates and nitrates), biological material, and industrial process emissions. The biological material, in the range of 3 to 17 percent of the sample weight, could have been from agricultural activity in the rural areas surrounding St. Joseph, from the extensive grain industry operations in the city, from natural sources such as pulverized leaf parts and pollen, or from a combination of these sources.

The high sulfate and nitrate concentrations (and percentages) were attributed partially to the fact that samples were analyzed shortly after being taken. The decay of sulfates and nitrates from hi-vol filters has been well documented in several studies. Also, chemical rather than microscopic analysis for these two components probably produced higher average concentrations because of the small size of these particles and the difficulty of quantitatively estimating their presence microscopically.

TABLE 17. PARTICLE TYPE CLASSIFICATION, MEAN DIAMETERS, AND POSSIBLE SOURCES

Component	Particle size, µm		Possible sources
	Mean	Range	
Mineral matter			
Quartz and feldspar	15	10-16	Windblown soil; any fugitive dust source (reentrained street dust, construction, agriculture, aggregate storage or processing, unpaved roads or lots, etc); long-range transport
Carbonates	7	6-9	
Clays and humus	10	8-12	
Other	12	8-14	
Asphalt	14	12-16	Pavement decomposition
Motor vehicles			
Rubber tire fragments	14	12-16	Motor vehicles
Combustion sources			
Glassy fly ash	4	3-5	Stationary combustion
Raw coal fragments	12	7-15	Coal-fired combustion; open coal storage; heavy industrial processes
Partially combusted fragments	4	3-5	Stationary and mobile combustion sources; secondary aerosols; industrial processes
Elemental carbon	0.2	0.2	Secondary aerosols; mobile source combustion
Ammonium sulfates, nitrates	n.d.		Secondary aerosols; some SO_4 and NO_3 can be soil-related
Biological matter			
Pollens, spores, conidia	20	10-30	Natural vegetation; long-range transport; food processing
Plant hairs, fragments			Natural vegetation; agricultural
Insect parts			Natural
Starch	12	12	Grain handling; food processing
Miscellaneous			
Nonmagnetic iron oxides	4	3-5	Rust; reentrained street debris; certain soils; combustion
Magnetic fragments	n.d.		All anthropogenic; reentrainment; construction; industrial process
Raw cement	20	12-30	Construction; cement or concrete production
Carbonate agglomerates	4		Industrial process; reentrainment
Paint spheres	30		Industrial process

TABLE 18. COMPOSITION OF INDIVIDUAL SAMPLES

Sample date	Site No.	Site name	TSP, ug/m^3	Percent composition by weight																					
				Mineral						Combustion					Biol.				Misc.				
				Quartz, feld	Carbonate	Clay humus	Other	Asphalt	Tire wear	Glossy fly ash	Raw coal	Partial comb.	Carbon part.	SO_4, NO_3	Pollen, spore	Plant parts	Insect parts	Starch	Iron oxides	Magnetic	Raw cement	CO_3 agglom.	Paint spheres
Av. conditions, weekday, south winds																									
9/18/80	1	Lake Road STP	134	12	25	8	4	<1	6	2	2	9	2	15	7	<1	<1	<1	7	<1	<1		
9/18/80	2	Rosecrans Airport	83	10	19	4	2	<1	5	3	<1	3	1	41	5	<1	<1	1	4	4			
9/18/80	3	Eighth and Edmond	47	4	17	1	1	<1	13	1	<1	9	1	33	2	<1	<1	15	2	<1	<1		
9/18/80	4	Fire Station	99	8	37	3	3	<1	12	2	<1	5	1	21	3	<1	<1	<1	4	<1			
9/18/80	5	Faraon Street STP	54	5	28	3	2	<1	7	1	<1	7	1	28	12	1	<1	<1	4	<1			
Weekday, west winds																									
9/30/80	1	Lake Road STP	84	10	39	5	7	<1	2	4	<1	3	1	15	6	<1	<1	<1	7	<1	<1		
9/30/80	2	Rosecrans Airport	83	12	40	3	6	<1	4	<1	<1	2	1	16	7	2	<1	<1	6	<1			
9/30/80	3	Eighth and Edmond	102	13	41	5	4	<1	8	1	<1	2	<1	11	3	<1	<1	2	7	<1	2		
9/30/80	4	Fire Station	73	13	41	4	6	<1	6	<1	<1	3	1	13	3	<1	<1	<1	8	<1	<1		
Weekend, NNW winds																									
10/18/80	1	Lake Road STP	58	38	19	7	7	<1	2	<1	<1	2	<1	15	2	1	<1	<1	6	<1			<1
10/18/80	3	Eighth and Edmond	53	21	31	4	4	<1	6	<1	<1	3	1	13	4	1	<1	5	6	<1	<1		
10/18/80	4	Fire Station	40	14	34	2	3	<1	8	<1	<1	6	2	14	9	2	<1	1	4	<1			
High windspeed, dry conditions, west winds																									
10/06/80	2	Rosecrans Airport	146	12	46	9	6	<1	2	<1	<1	1	<1	14	5	<1	<1	<1	4	<1	<1		
10/06/80	3	Eighth and Edmond	147	12	45	8	7	<1	4	<1	<1	2	<1	9	3	<1	<1	<1	9	<1	<1		
10/06/80	5	Faraon Street STP	118	14	41	9	6	<1	3	<1	<1	2	<1	11	5	<1	<1	<1	8	<1			
Anomaly																									
10/12/80	5	Faraon Street STP	157	30	20	6	6	<1	7	<1	<1	5	1	3	9	1	<1	2	4	<1		5	
Mean			92	14	33	5	5	<1	6	1	<1	4	1	17	5	<1	<1	2	6	<1	<1		

TABLE 19. MICROSCOPY SAMPLES SUMMARIZED BY MAJOR SOURCE CATEGORY

Sample date	Site No.	TSP, µg/m³	Mineral matter		Motor vehicle emissions		Combustion products				Biological matter		Miscellaneous	
							Primary		Sulfates and nitrates					
			Percent	µg/m³	Percent	µg/m³	Percent	µg/m³	Percent	µg/m³	Percent	µg/m³	Percent	µg/m³
Average conditions, weekday, south winds														
9/18/80	1	134	49	66	6	8	15	20	15	20	7	9	7	9
9/18/80	2	83	36	30	5	4	7	6	41	34	6	5	4	3
9/18/80	3	47	23	11	13	6	11	5	33	16	17	8	2	<1
9/18/80	4	99	51	50	12	12	8	8	21	21	3	3	4	4
9/18/80	5	54	38	20	7	4	9	5	28	15	13	7	4	2
Weekday west winds														
9/30/80	1	84	61	51	2	2	8	7	15	12	6	5	7	6
9/30/80	2	83	61	51	4	3	3	3	16	13	9	7	6	5
9/30/80	3	102	63	64	8	8	3	3	11	11	5	5	9	9
9/30/80	4	73	65	47	6	4	4	3	13	10	3	2	8	6
Weekend, NNW winds														
10/18/80	1	58	71	41	2	1	2	1	15	9	3	2	6	3
10/18/80	3	53	60	32	6	3	4	2	13	7	10	5	6	3
10/18/80	4	40	53	21	8	3	8	3	14	6	12	5	4	1
High windspeed, dry conditions, west winds														
10/06/80	2	146	73	107	2	3	1	2	14	20	5	7	4	6
10/06/80	3	147	72	106	4	6	2	3	9	13	3	4	9	13
10/06/80	5	118	70	83	3	4	2	2	11	13	5	6	8	9
Anomaly														
10/12/80	5	157	62	97	7	11	6	9	3	5	12	19	9	14

Estimated source contributions on different days were compared from the data in Table 19. Winds from the west, on September 30 and October 6, appeared to cause higher mineral content and lower anthropogenic (related to man's activity) impact than winds from the south. Mineral contents on October 6 were the highest of any of the 16 samples; this was also a day with high windspeeds and dry soil surfaces (12 days since rain). The weekend samples of October 18 had the lowest concentrations from all anthropogenic sources, but the percentages were not substantially lower than on other days because of the low TSP concentrations for the three weekend samples.

The October 12 sample with the unexpectedly high TSP concentration was found to have 5 percent by weight of spherical carbonate agglomerates, a particle type not seen in quantity on any of the other filters. According to IITRI, the spherical shape indicated the carbonate had crystallized from solution. Also, these particles were intermixed with fungal conidia and other biological matter. It was hypothesized that the added contribution on the anomalous filter was mist from some sewage pumping operation occurring near the sampler. Several exhaust vents from the pump station were located on the same roof as the sampler. Because of the strong possibility that this sample was contaminated by local emissions, it was excluded from the statistical summary for Site 5.

A few other distinctive particles were noted on some filters. Half of the 16 filters had quantities of raw cement fragments on them, including all four of the filters from the Eighth and Edmond site. This was interpreted to mean that a concrete production plant or large-scale construction activities were contributing significantly to measurements taken at the Eighth and Edmond site and to a lesser extent to emissions measured at Sites 1, 2, and 4. Multiple sources of these cement particles were a possibility. The Eighth and Edmond site also had major impacts (averaging almost 6 percent) from starch grains, indicating grain handling or processing emissions. This was further substantiated by relatively high percentages of pollen and spores for a center city site. Other distinctive particles were large uncombusted coal fragments, almost certainly from a local coal-burning facility, and white paint spheres on one sample, probably due to local spray painting.

The sampling sites were not selected to provide concurrent sampling upwind and at various downwind distances from the city. A cursory evaluation of buildup and depletion of concentrations of various components in the prevailing wind direction was not productive. The evaluation was not thorough enough to conclude that small particle components such as sulfates, elemental carbon, and combustion products were mainly locally generated, but no evidence of transport was found either.

The fairly large physical particle sizes also indicated that much of the particulate was locally generated. Based on the particle sizes from Table 17 and average percentages for each of these particle types, a mass mean diameter of about 8 μm was calculated. This is comparable to an aerodynamic diameter of 12 to 14 μm.

SUMMARY

The microscopic analysis of selected filters from five sites in St. Joseph proved to be quite informative because there were substantial percentages of the particles that were types other than mineral matter, and which therefore could be associated with possible sources. The 16 samples described above have been combined by site in Table 20 for comparison with the microinventory data. No attempt has been made to arrive at average values by site for each particle type because of the gross statistical inadequacy of any such averages.

It should be reemphasized that microscopic particle identification data at best are semiquantitative. The major limitations (assuming experienced observers and a good analysis procedure) are conversion of linear size data to volumetric size data and inability to accurately measure the mass of particles in the fine particle size range (<2 μm).

TABLE 20. SUMMARY OF PARTICLE CLASSIFICATIONS BY SITE

Site/location	Range of sample composition, % by weight					
	Mineral matter	Motor vehicle emissions	Combustion products		Biological matter	Miscellaneous
			Primary	SO_4, NO_3		
1 Lake Rd STP	49-71	2-6	2-15	15	3-7	6-7
2 Rosecrans Airport	36-73	2-5	1-7	14-41	5-9	4-6
3 Eighth and Edmond	23-72	4-13	2-11	9-33	3-17	2-4
4 Fire Station	51-65	6-12	4-8	13-21	3-12	4-8
5 Faraon Rd STP	38-70	3-7	2-9	3-28	5-13	4-9
All	23-73	2-13	1-15	3-41	3-17	2-9

SECTION 6

REASONABLY AVAILABLE CONTROL TECHNOLOGY (RACT) EVALUATION OF PARTICULATE CONTROLS ON MAJOR POINT SOURCES

MAJOR POINT SOURCE IDENTIFICATION

The industrial point sources present in St. Joseph, Missouri, consist of a variety of industries and types of sources. For the most part, the particulate emission sources are not "major," with major defined for purposes of this evaluation as a facility containing emission points having an aggregate 100 tons/yr or more of particulate emissions. Data from the National Emission Data System indicate that only four sources in St. Joseph are major point sources according to this definition. Three of these major sources are in the feed and grain industry while the fourth major source is a boiler.

The following subsections present an evaluation of the particulate controls on the major point sources with respect to whether they constitute RACT. The evaluation is based upon emission inventory data supplied by the Missouri Department of Natural Resources (DNR) on sources, emissions, controls, and control efficiencies. In addition, the DNR conducted several site inspections to update and validate data contained in the inventory. Because some of the emission data may be dated, findings noncompliant with RACT should be regarded as tentative. Site inspections will be required before the determination can be considered absolute.

Reasonably available control technology is defined as the lowest emission limit that a particular source is capable of meeting by the application of a control technology that is reasonably available considering technological and economic feasibility.[1] The determination of RACT is based upon data obtained in prior studies conducted by PEDCo Environmental, Inc., and others on controls for various source categories. Consequently, the recommended control measures may not be technically and economically feasible for a specific plant. Plant-specific technical and economic analyses should be performed prior to requiring the recommended controls. These analyses will ensure that the additional controls can be retrofitted to the existing operation and that the cost of the controls is not prohibitive.

RACT EVALUATION OF PARTICULATE POINT SOURCES IN THE FEED AND GRAIN INDUSTRY

In St. Joseph, 93 emission points at 9 facilities can be classified as part of the feed and grain industry. These emission points, their annual emissions, and their control devices are summarized in Table 21. The table indicates that on an aggregate source emission basis, only three of these facilities can be classified as major. The 3 major facilities contain 43 emission point sources consisting of a variety of operations common in the feed and grain industry.

Quaker Oats Company

The Quaker Oats Company facility located on South 11th Street in St. Joseph contains 32 separate emission points for particulate matter. The facility processes corn, wheat, and oats in a variety of operations. Annual throughputs for the grains are about 440,000 tons of corn, 650,000 tons of wheat, and 700,000 tons of oats. Principal products are flour and cereals containing these grains.

The total particulate emissions from this facility in 1973 (latest available data) were 497 tons. National Emission Data System (NEDS) information indicates that only one emission point is not in compliance with State limitations. This source emits about 100 tons more than allowed. The other 31 sources are well within compliance; they emit only 221 tons, but are allowed 1100 tons per year.

Most of the emission points at this facility are controlled by high-efficiency particulate removal devices. Eighteen emission points are controlled by fabric filters having a reported efficiency of 99.5 percent. For these sources, fabric filters would be classified as equivalent or better than RACT because of the high collection efficiency. Nine sources are controlled by centrifugal collectors with reported efficiencies of 90 percent. This level of control results in emissions of less than 5 tons per year for eight sources. None of these sources approaches the allowable emission level. Because of the high level of control, these eight sources are considered as having control equivalent to or better than RACT.

One other source, the oat flour operation (NEDS point ID 13), has reported emissions of 19 tons/yr with an allowable level of 80 tons/yr. This level is higher than other flour operations at the plant. Since fabric filters are employed throughout the facility, this device is reasonably available. Therefore, it is recommended that a fabric filter be employed to further control the emissions from this source.

TABLE 21. SUMMARY OF ACTUAL AND ALLOWABLE PARTICULATE MATTER EMISSIONS AND CONTROL EFFICIENCIES OF FEED AND GRAIN OPERATIONS IN ST. JOSEPH, MISSOURI

Company	Source	Particulate matter emissions, tons/yr		Control device	Efficiency, %
		Actual	Allowable		
Pillsbury "B"	RR load out	4	Unknown	Cyclones/fab. fltr.	90.0
Pillsbury "B"	RR dump pit	4	Unknown	Cyclones	90.0
Schreiber Mills	Feed mfg.	21	51	Centrifugal col.	90.0
Quaker Oats	Corn dryer	1	Unknown	None	N.A.
Quaker Oats	Flour drying	3	20	None	N.A.
Quaker Oats	Flour handling	1	92	Centrifugal col.	90.0
Quaker Oats	Corn processing	2	80	Centrifugal col.	90.0
Quaker Oats	Corn cracking	3	92	Fabric filter	99.5
Quaker Oats	Corn processing	1	76	Fabric filter	99.5
Quaker Oats	Corn meal	1	58	Fabric filter	99.5
Quaker Oats	Corn grits	3	66	Fabric filter	99.5
Quaker Oats	Wheat flour	6	72	Fabric filter	99.5
Quaker Oats	Wheat processing	3	72	Centrifugal col.	90.0
Quaker Oats	Corn flour	1	26	Centrifugal col.	90.0
Quaker Oats	Oat flour	19	80	Centrifugal col.	90.0
Quaker Oats	Wheat processing	2	86	Fabric filter	99.5
Quaker Oats	Oat processing	1	67	Fabric filter	99.5
Quaker Oats	Oat processing	15	31	None	N.A.
Quaker Oats	Flour	2	126	Centrifugal col.	90.0
Quaker Oats	Rolled oats	3	70	Centrifugal col.	90.0
Quaker Oats	Oat groats	4	60	Fabric filter	99.5
Quaker Oats	Oat groats	1	56	Fabric filter	99.5
Quaker Oats	Oat groats	19	31	None	N.A.
Quaker Oats	Corn grits	2	28	Fabric filter	99.5
Quaker Oats	Wheat bran	5	16	Fabric filter	99.5
Quaker Oats	Oat groats	3	92	Fabric filter	99.5
Quaker Oats	Oat dust	3	92	Fabric filter	99.5

(continued)

TABLE 21 (continued)

Company	Source	Particulate matter emissions, tons/yr		Control device	Efficiency, %
		Actual	Allowable		
Quaker Oats	Oat dust	3	92	Fabric filter	99.5
Quaker Oats	Oat groat	6	76	Fabric filter	99.5
Quaker Oats	Oat hulls	3	84	Fabric filter	99.5
Quaker Oats	Grain processing	2	106	Fabric filter	99.5
Quaker Oats	Corn germ	4	20	Centrifugal col.	90.0
Quaker Oats	Grain receiving	57	144	Fabric filter	99.5
Quaker Oats	Grain transfer	276	180	None	N.A.
Quaker Oats	Grain dust	42	89	Fabric filter	99.5
Carnation Co.	Grain receiving	1	82	Fab.fltr./ centrif. col.	98.0
Carnation Co.	Grain storage	2	73	Fab.fltr./ centrif. col.	98.0
Carnation Co.	Grain transfer	2	73	Fab.fltr./ centrif. col.	98.0
Carnation Co.	Grain cleaning	3	101	Fab.fltr./ centrif. col.	98.0
Carnation Co.	Grain drying	13	73	Not indicated	N.A.
Carnation Co.	Grain milling	10	101	Fab.fltr./ centrif. col.	98.0
Carnation Co.	Grain mixing	3	73	Centrifugal col.	98.0
FAR-MAR-CO	Grain receiving	0	25	Fabric filter	99.9
FAR-MAR-CO	Grain cleaning	0	158	Fabric filter	99.9
FAR-MAR-CO	Grain transfer	0	158	Fabric filter	99.9
FAR-MAR-CO	Garner bin holding	0	158	Fabric filter	99.9
FAR-MAR-CO	Bean cleaner	1	158	Fabric filter	99.9
FAR-MAR-CO	Soybean prep./solvent extractor	1	158	Fabric filter	99.9
FAR-MAR-CO	Soy flour milling	0	174	Fab.fltr./ centrif. col.	99.9
FAR-MAR-CO	Soybean prep.	11	174	Fabric filter	99.0

(continued)

TABLE 21 (continued)

Company	Source	Particulate matter emissions, tons/yr		Control device	Efficiency, %
		Actual	Allowable		
FAR-MAR-CO	Grain mixing	2	31	Centrifugal col.	95.0
FAR-MAR-CO	Grain mixing	2	31	Centrifugal col.	95.0
Ralston Purina	RR unloading	1	73	Centrifugal col.	95.0
Ralston Purina	Truck unloading	11	23	Centrifugal col.	93.0
Ralston Purina	Grain milling	29	52	Not indicated	N.A.
Ralston Purina	Feed mixing	96	53	Not indicated	N.A.
Ralston Purina	Pelletizer	1	50	Centrifugal col.	98.0
Ralston Purina	Pelletizer	1	50	Centrifugal col.	98.0
Farmland Soybean	Truck dump	0	193	Fabric filter	99.9
Farmland Soybean	Truck dump	0	193	Fabric filter	99.9
Farmland Soybean	RR dump	0	133	Fabric filter	99.9
Farmland Soybean	Grain cleaning	1	194	Fabric filter	99.9
Farmland Soybean	Garner bin	1	194	Fabric filter	99.9
Farmland Soybean	Garner bin	1	194	Fabric filter	99.9
Farmland Soybean	Dust bin	0	5	Fabric filter	99.9
Farmland Soybean	Hull cracking	1	171	Fabric filter	99.9
Farmland Soybean	Hull screening	19	180	Centrifugal col.	96.0
Farmland Soybean	Hull screening	1	171	Fabric filter	99.9
Farmland Soybean	Flaking grits	3	176	Centrifugal col.	96.0
Farmland Soybean	Hull grinding	0	179	Fabric filter	99.9
Farmland Soybean	Flash desol.	0	37	Fabric filter	99.9
Farmland Soybean	Meal toaster	1	144	Gas scrubber	99.5
Farmland Soybean	Meal cooler	1	90	Centrifugal col.	95.0
Farmland Soybean	Meal cooler	1	90	Centrifugal col.	99.5
Farmland Soybean	Meal cooler	1	90	Centrifugal col.	99.5
Farmland Soybean	Meal blower	0	144	Fabric filter	99.9
Farmland Soybean	Hammermills	1	144	Centrifugal col.	98.0
Farmland Soybean	Meal transfer	1	144	Fabric filter	99.9
Farmland Soybean	Meal bagging	0	110	Fabric filter	99.9

(continued)

TABLE 21 (continued)

Company	Source	Particulate matter emissions, tons/yr		Control device	Efficiency, %
		Actual	Allowable		
Farmland Soybean	Reject system	0	63	Fabric filter	99.9
Farmland Soybean	Flour bins	0	195	Fabric filter	99.9
Farmland Soybean	Hammermills	0	90	Fabric filter	99.9
Pillsbury Co.	Truck dump	15	Unknown	Cyclone	80.0
Pillsbury Co.	RR receiving	15	Unknown	Cyclone	80.0
Pillsbury Co.	Grain cleaning	0	Unknown	Not indicated	N.A.
Pillsbury Co.	RR loadout	30	Unknown	Cyclones	80.0
Pillsbury Co.	Grain dryer	90	Unknown	None	N.A.
MFA Feed Div.	Receiving pit	10	20	None	N.A.
MFA Feed Div.	Corn cooler	0	Unknown	Cyclones	Unknown
MFA Feed Div.	Pellet mill	0	Unknown	Cyclone	Unknown
MFA Feed Div.	Pellet mill	0	Unknown	Cyclone	Unknown
MFA Feed Div.	Truck loadout	0	8	Not indicated	N.A.
MFA Feed Div.	Rail loadout	0	16	Not indicated	N.A.

N.A. = Not applicable

Five sources at Quaker Oats are not indicated as having any control. The first source is the corn dryer (NEDS point ID 01). This source is estimated to have emissions totaling only 1 ton/yr with no allowable level indicated. If this is a column dryer, as indicated by the low level of emission, no control is equivalent to RACT.[2]

The second uncontrolled source at Quaker Oats is the flour drying exhaust (NEDS point ID 03). This source also exhibits a low emission rate of 3 tons/yr (0.43 lb/ton processed) versus an allowable level of 20 tons/yr. No control would constitute RACT for this source considering the already low emission level.

The third uncontrolled source is an oat processing operation (NEDS point ID 16). This point emits 15 tons/yr (1.27 lb/ton processed) versus an allowable level of 31 tons/yr. Other grain processing operations at the facility are controlled with fabric filters. Therefore, this operation should also be controlled with a fabric filter. This possibility should be investigated further with plant-specific data.

The next uncontrolled source at the Quaker Oats facility is an oat groat processing operation (NEDS point ID 21). This point emits 19 tons per year (0.79 lbs/ton processed) versus an allowable rate of 31 tons per year. Since other oat groat processing operations are controlled with fabric filters, this one should also be controlled with a fabric filter. Further investigation of this possibility with plant-specific data is recommended.

The most significant uncontrolled source at the Quaker Oats facility is the transfer of grain to bins after receipt (NEDS point ID 32). This source emits 276 tons per year of particulates with no control device to limit these emissions. Because of the significance of these emissions and the noncompliance with the allowable level of emission, no control cannot be considered as RACT for this source.

The control of emissions from transferring and conveying grain in large elevators is often carried out by ducting many individual dust sources to a common dust collector system. This is commonly done for the dust sources in the headhouse. Thus, aspiration systems serving elevator legs, transfer points, bin vents, etc., may all be ducted to one collector. In these control systems, it is desirable to enclose all possible conveyors so that little particulate matter can be emitted. Trippers are usually hooded and ventilated to cyclones or fabric filters. Although either cyclones or fabric filters may be used as the collection device, a much higher efficiency will be obtained with the fabric filter. Fabric filters are employed on other operations throughout the Quaker Oats facility and are indicated as being employed on grain transferring operations at two other facilities in St. Joseph. Therefore, a fabric filter satisfies the criterion of being reasonably available for application on grain transferring operations and is the recommended control for RACT on this source at Quaker Oats.

Ralston Purina Company

The Ralston Purina Company facility located on South Highway 169 in St. Joseph contains six separate emission points for particulate matter. The facility processes about 64,000 tons/yr of grain by milling, mixing, and pelletizing to produce feed.

The total particulate emissions from this facility in 1978 were 139 tons. The NEDS information indicated one source as being out of compliance with the State limitation by 43 tons/yr. The other sources are well within compliance, emitting 43 tons/yr versus an allowed level of 248 tons/yr.

Most of the sources at the facility are controlled by high-efficiency centrifugal collectors. The railroad unloading operation is controlled by such a device, with an efficiency of 95 percent. The two pelletizers are controlled by centrifugal collectors of 98 percent efficiency. These three operations are considered to have RACT applied with the indicated high level of control.

The truck unloading operation (NEDS point ID 02) is also controlled with a high-efficiency centrifugal collector. The reported efficiency is 93 percent. Other grain receiving operations in St. Joseph are controlled with fabric filters, either separately or in conjunction with cyclones. Since fabric filters are employed at other facilities, this control is reasonably available and is recommended to further reduce the reported emissions of 11 tons/yr.

The grain milling operation (NEDS point ID 03) does not have a control device indicated. However, comparison of the actual emissions versus potential emissions determined by applying the emission factor of 5 lb/ton indicates a control level of 82 percent. This level of control provides an emission reduction of 45 percent below the allowable level. The grain milling operations, however, are controlled with cyclones and/or fabric filters with at least a 98 percent control efficiency. Therefore, it is recommended that the level of control for this source be increased to at least 98 percent.

The feed mixing operation (NEDS point ID 04) is indicated as being uncontrolled and out of compliance. Because of the high level of emissions and the noncompliance status, no control is not considered as RACT for this source. Examination of other facilities in the St. Joseph area revealed that three such operations are controlled to 95 percent removal or better by use of centrifugal collectors. Recovery of the emissions from the feed mixing operation will also provide an economic benefit because of the value of the captured grain particles. In view of the availability of control technology for this process, a centrifugal collector of at least 95 percent efficiency is recommended as RACT.

Pillsbury Company

The Pillsbury Company's Elevator "A" located in St. Joseph contains five sources of particulate emissions. The facility handles about 300,000 tons of grain/yr. A small percentage of the grain is cleaned and dried before loadout for shipment.

The total particulate emissions from this facility in 1978 were 150 tons. The NEDS information did not contain the allowable emission levels for the point sources, and no determination could be made as to the compliance status of each point source.

Three of the sources are controlled by cyclones with listed efficiencies of 80 percent. The sources include the truck and railcar receiving operations (NEDS point ID's 01 and 02) and the railcar loading operations (NEDS point ID 04). Total controlled emissions from these sources are 60 tons/yr. Examination of similar sources in St. Joseph reveals that of the six railcar unloading operations, two employ centrifugal collectors with efficiencies of 90 to 95 percent and four employ fabric filters with efficiencies ranging from 98 to 99.9 percent. Of the five truck unloading operations in St. Joseph, one employs a centrifugal collector of 93 percent efficiency and four employ fabric filters with efficiencies ranging from 98 to 99.9 percent. The one other railcar loading operation employs a combination of a cyclone and a fabric filter to achieve 90 percent control. In view of the high control efficiencies achieved at other similar operations in St. Joseph, the use of 80 percent efficient cyclones at Pillsbury does not represent RACT. It is recommended that measures to achieve at least 98 percent efficiency be employed on the railcar and truck unloading operations and the railcar loading operation to constitute RACT on these sources.

No control device is indicated on the grain cleaning and receiving operations (NEDS point ID 05), but the listed emissions indicate a high level of control (about 97 percent). If the emissions level can be verified, this operation should be considered as employing RACT because of the low emission level (less than 1 ton/yr).

No control is indicated as being employed on the rack grain dryer (NEDS point ID 04) at Pillsbury. Given the 90 tons/yr of emissions, it is reasonable to require controls for this source. Available control technology for rack dryers includes screens with or without vacuum cleaning. To satisfy the RACT requirement, it is recommended that the facility install screens of at least 24 mesh to achieve a level of control equivalent to about 60 percent, which will provide a 54 tons/yr decrease in particulate emissions.[2]

RACT EVALUATION OF PARTICULATE CONTROLS ON BOILERS

St. Joseph has 19 boilers at 10 facilities. These boilers, their sizes, fuels, emissions, and controls are summarized in Table 22. As can be seen from the Table, the majority (16) of these units burn only fuels that have relatively small emissions of particulate matter such as fuel oil, natural gas, or propane. These units do not satisfy the criteria for a major facility, with each unit's particulate emission level less than 10 tons/yr. Each can be considered as applying RACT, however, since the burning of these "clean" fuels is believed to constitute RACT.

The three boilers burning coal as a fuel have significant particulate emission levels. These boilers are located at the St. Joseph Power & Light Lake Road plant and together constitute the fourth major point source. The first unit listed (309×10^6 Btu/h) is Boiler 4 at the Lake Road Plant. According to the emission inventory, this unit emits 393 tons/yr of particulate matter when burning coal, while allowed only 227 tons/yr. The present control device is indicated as being a centrifugal collector with an efficiency of about 87 percent removal. For boilers of capacities greater than 250×10^6 Btu/h, RACT as specified by states in their State Implementation Plans is usually equivalent to a control level of about 0.1 to 0.2 pound of particulate emitted per million Btu's of heat input. This level of control requires an efficiency of about 95 to 99 percent, which can be achieved by application of electrostatic precipitators, fabric filters, or wet scrubbers. Assuming a fairly lenient level of control (95 percent), application of RACT on this boiler would result in emissions of 147 tons/yr of particulate matter or a reduction of 246 tons/yr from present emission levels.

The second coal-fired unit is Boiler 5 (367×10^6 Btu/h) at the Lake Road Plant. The unit emits 31 tons/yr of particulate matter while allowed 270 tons/yr. The unit is a cyclone boiler that has a comparatively low emission rate for a large utility boiler (about 12 percent of the rate from a pulverized unit). Control at the 99.6 percent level is provided by an electrostatic precipitator in combination with a centrifugal collector. Because of the low emission rate and the compliance status of the unit, it should be considered as having the equivalent or better than RACT already applied.

The third coal-fired unit is Boiler 6 at the Lake Road Plant. Like Boiler 5, it is a cyclone type boiler with a lower particulate emission rate than typical large utility pulverized

TABLE 22. SUMMARY OF ACTUAL AND ALLOWABLE PARTICULATE MATTER EMISSIONS AND CONTROL EFFICIENCIES OF BOILERS IN ST. JOSEPH, MISSOURI

Company	Boiler capacity, 10 Btu/h	Boiler fuel	Particulate matter emissions, tons/yr		Control device	Efficiency, %
			Actual	Allowable		
St. Joe L. & P.	120	Oil/gas	1	109	Scrubber	93.0
St. Joe L. & P.	120	Oil/gas	2	109	Scrubber	93.0
St. Joe L. & P.	Not ind.	Gas/propane	0	Not ind.	None	N.A.
St. Joe L. & P.	228	Gas	1	359	None	N.A.
St. Joe L. & P.	193	Oil/gas	1	142	None	N.A.
St. Joe L. & P.	309	Coal/gas/oil	393[a]	227	Centrif. col.	86.6
St. Joe L. & P.	367	Coal/gas/oil	31	270	ESP/cyclone	99.6
St. Joe L. & P.	1070	Coal/gas	131	787	Cyclone	98.7
St. Joe L. & P.	193	Oil/gas	1	142	None	N.A.
St. Joe L. & P.	228	Oil/gas	7	168	None	N.A.
Rosecrans Apt.	14	Oil	0	459	None	N.A.
Dugdale Pkg.	16	Gas	1	1	None	N.A.
Dugdale Pkg.	14	Oil	4	4	None	N.A.
Anchor Labs.	13	Gas	1	15	None	N.A.
Globe-Union	Not ind.	Gas	0.18	Not ind.	None	N.A.
Seitz Pkg.	5	Gas	1	10	None	N.A.
Quaker Oats	37	Gas/oil	3	15	None	N.A.
Ralston Purina	5	Gas/oil	0	13	None	N.A.
Meth. Med. Center	13	Gas/oil	1	33	None	N.A.
U.S. Army Reserve	1	Gas	0	26	None	N.A.
U.S. Army Reserve	1	Gas	0	26	None	N.A.
U.S. Army Reserve	1	Oil	0	26	None	N.A.
Carnation Co.	11	Gas	0	6	None	N.A.
Carnation Co.	1	Gas	0	1	None	N.A.
Seitz Foods	20	Gas/oil	1	1	None	N.A.

N.A. = Not applicable

[a] Emissions when burning coal; natural gas is the primary fuel used at this time.

units. The unit emits 131 tons/yr while allowed 787 tons per year. The control device listed is a centrifugal collector of 98.7 percent efficiency. This is a very high efficiency for such a device and an error has probably been made in the device identification or the efficiency listing. Verification of the data should be made to ascertain if the listed emissions are correct. If the efficiency is correct, the unit can be considered as applying RACT because of the low emission rate (0.04 lb/ 10^6 Btu) versus the allowable level (0.2 lb/10^6 Btu).

RACT EVALUATION OF PARTICULATE POINT SOURCES IN THE ASPHALT/ CONCRETE INDUSTRY

St. Joseph has three plants containing four sources of particulate emissions that may be classified as asphalt/concrete plants. These points, their emissions, and their control devices are summarized in Table 23. The table indicates that on a total source basis, none of these facilities may be classified as major, and no further analysis will be undertaken.

RACT EVALUATION OF PARTICULATE CONTROLS ON INCINERATORS

St. Joseph has two incinerators as summarized in Table 24. Neither has particulate emissions in quantities that would qualify as major, and therefore a RACT evaluation was not made.

RACT EVALUATION OF PARTICULATE CONTROLS FOR MEAT PACKING AND SLAUGHTERHOUSES.

The two meat packing/slaughterhouses in St. Joseph contain four particulate emission sources as summarized in Table 25. Neither of the facilities qualifies as major because of the low quantities of emissions, and a RACT evaluation was not made.

RACT EVALUATION OF LEAD ACID BATTERY MANUFACTURING

The one lead acid battery manufacturing facility in St. Joseph contains 10 emission points. As illustrated in Table 26, the facility is an insignificant source of particulate emissions, and a RACT evaluation was not performed.

SUMMARY

Twelve emission points have been tentatively identified as not meeting RACT requirements. These sources are shown in Table 27. Again it is emphasized that some of the data on which the analysis was based are possibly dated; plant inspections are

TABLE 23. SUMMARY OF ACTUAL AND ALLOWABLE PARTICULATE MATTER EMISSIONS AND CONTROL EFFICIENCIES OF ASPHALT/CONCRETE PLANTS IN ST. JOSEPH, MISSOURI

Company	Source	Particulate matter emissions, tons/yr		Control device	Efficiency, %
		Actual	Allowable		
Herzog Cont.	Loading, other sources	23	348	None	N.A.
Herzog Cont.	Rotary dryer (oil)	18	551	Wet scrubber	99.6
St. Joseph	Ready mix concrete batching	2	41	Gravity col./ fabric fltr.	50.0
Keller Const.	Rotary dryer	3	7	Centrifugal col./ wet scrub.	99.0

N.A. = Not applicable

TABLE 24. SUMMARY OF ACTUAL AND ALLOWABLE PARTICULATE MATTER EMISSIONS AND CONTROL EFFICIENCIES OF INCINERATORS IN ST. JOSEPH, MISSOURI

Company	Type incinerator	Particulate matter emissions, tons/yr		Control device	Efficiency, %
		Actual	Allowable		
Meth. Med. Center	Mult. Chamber	20	Unlimited	None	N.A.
St. Joseph State Hospital	Mult. Chamber	2	Unlimited	None	N.A.

N.A. = Not applicable

TABLE 25. SUMMARY OF ACTUAL AND ALLOWABLE PARTICULATE MATTER EMISSIONS AND CONTROL EFFICIENCIES OF MEAT PACKING AND SLAUGHTERHOUSES IN ST. JOSEPH, MISSOURI

Company	Source	Particulate matter emissions, tons/yr		Control device	Efficiency, %
		Actual	Allowable		
Armour & Co.	I-C engine (oil)	1	Unlimited	None	N.A.
Armour & Co.	Blood drying	10	N.A.	Centrif. col.	99.0
Armour & Co.	Slaughtering	1	Unlimited	None	N.A.
Seitz Pkg.	Meat smokehouse	1	16	None	N.A.

N.A. = Not applicable

TABLE 26. SUMMARY OF ACTUAL AND ALLOWABLE PARTICULATE MATTER EMISSIONS AND CONTROL EFFICIENCIES OF LEAD BATTERY MANUFACTURING IN ST. JOSEPH, MISSOURI

Company	Source	Particulate matter emissions, tons/yr		Control device	Efficiency, %
		Actual	Allowable		
Globe-Union	Paste mixers	0	25	Scrubber/ centrif. col.	98.0
Globe-Union	Paste mixers	0	41	Fabric filter	99.8
Globe-Union	Lead oxide ballmill	0	21	Fabric filter	99.8
Globe-Union	Panel drying ovens	0	26	Centrif. col.	99.0
Globe-Union	Panel pasting	1	26	None	N.A.
Globe-Union	Acid mix/oxide storage	0	46	Scrubber/ centrif. col.	99.0
Globe-Union	Scrap lead	0	10	Centrif. cols.	98.0
Globe-Union	Separators/cured plates	0	6	Centrif. col.	99.8
Globe-Union	Small parts casting	0	2	Centrif. col.	99.8
Globe-Union	Central vacuum system	0	2	Centrif. col./ fab. fltr.	99.0

N.A. = Not applicable

TABLE 27. RACT EVALUATION SUMMARY

Source	Existing			Recommended			
	Control device	Efficiency, %	Emissions with existing control device, tons/yr	Control device	Efficiency, %	Emission reduction, tons/yr	Emissions with with recommended controls, tons/yr
Quaker Oats							
13 oat flour	centrif. col	90	19	fabric filter	99.5	18	1
16 oat processing	None		15	fabric filter	99.5	14	1
21 oat groat	None		19	fabric filter	99.5	18	1
32 grain transfer	None		276	fabric filter	99.5	275	1
Ralston Purina							
02 truck unloading	centrif. col	93	11	fabric filter	99.5	10	1
03 grain milling	not indicated	45	29	fabric filter	98.0	28	1
04 feed mixing	not indicated		96	centrif. col.	95.0	91	5
Pillsbury							
01 truck dump	cyclone	80	15	fabric filter	98.0	13	2
02 RR receiving	cyclone	80	15	fabric filter	98.0	13	2
04 RR loadout	cyclone	80	30	fabric filter	98.0	27	3
05 grain dryer	None		90	screens	60.0	53	37
St. Joseph P&L							
02 boiler No. 4	centrif. col.	87	193[a]	precipitators	95.0	247	146
Total			1008			807	201

[a] Emission when burning coal. Natural gas is the primary fuel used at this time.

required before final determinations are possible. If the recommended control measures are technologically and economically feasible and can be implemented, there will be a net emission reduction of 807 tons/yr from the point sources in St. Joseph.

REFERENCES

1. Memorandum defining RACT, from the Assistant Administrator of the Office of Air and Waste Management. December 9, 1976.

2. Standards Support and Environmental Impact Statement Volume I: Proposed Standards of Performance for the Grain Elevator Industry. U.S. Environmental Protection Agency. Office of Air and Waste Management. Office of Air Quality Planning and Standards. Emission Standards and Engineering Division. EPA-450/2-77-001a. January 1977. p. 2-7.

SECTION 7

SYNTHESIS OF ANALYTICAL TECHNIQUES

SYNTHESIS METHODOLOGY

Five independent analytical techniques were used to study the particulate problem in St. Joseph. The research was focused on answering two questions:

1. Is the particulate problem in St. Joseph due to extra-regional sources or sources in the St. Joseph area? An unknown part of the total concentration may be due to long-range transport from Kansas City or from rural fugitive dust. Both of these source categories are beyond the control of St. Joseph enforcement agencies.

2. If part of the particulate problem is due to sources within the St. Joseph area, what are the specific sources? Identification of specific sources will allow design of specific control measures that can be implemented by local agencies.

Four of the five analytical techniques give a partial answer to both questions. The RACT analysis was useful in treating the second question only. The process used to synthesize the results of the techniques is shown in Figure 11. The results of the techniques applicable to the first question are given in Table 28. A similar table for the second question appears as Table 29.

RESULTS

Extra-Regional or Local Sources

Statistical Analysis--

If high concentrations in St. Joseph are caused solely by extra-regional sources, i.e., long-range transport and rural fugitive dust, monitoring data from the three St. Joseph sites and the KCI site would show similar characteristics with regard to seasonal and daily patterns, pollution and concentration roses, and intersite TSP correlations. The similarity does not exist. In fact, at least two of the St. Joseph sites appear to be directly influenced by local sources.

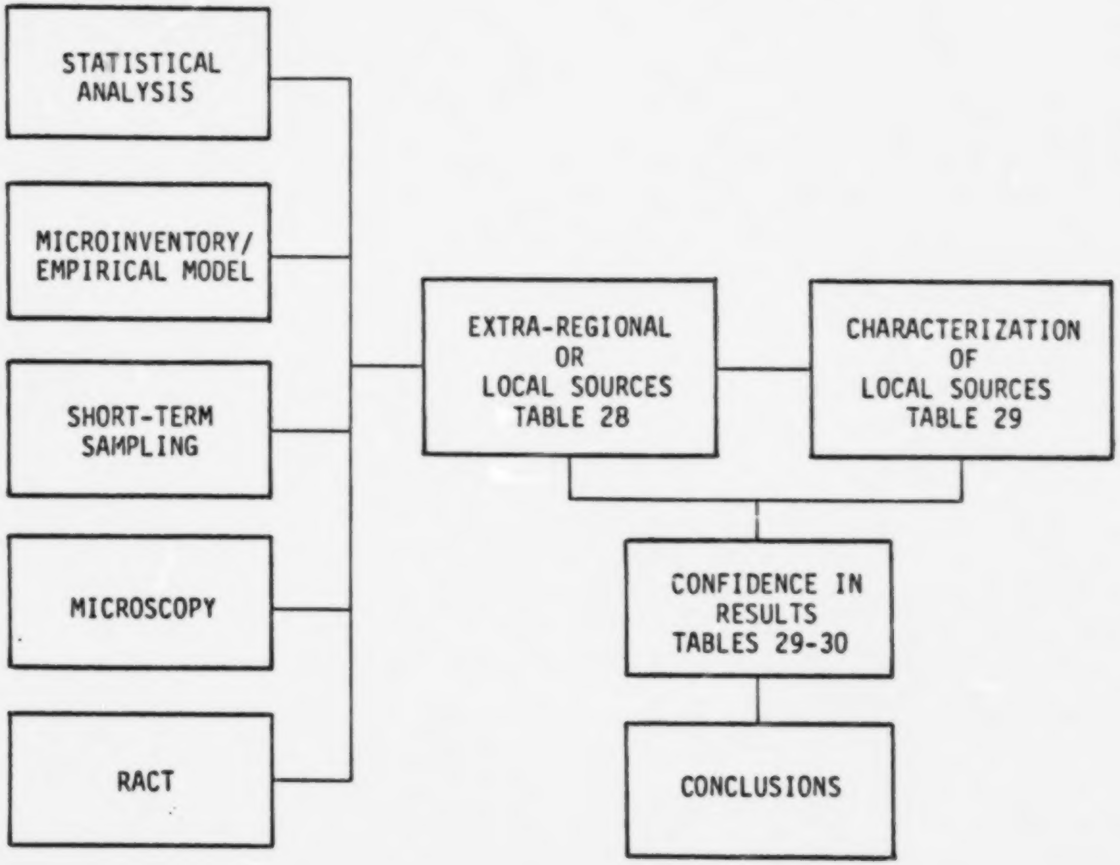

STATISTICAL ANALYSIS
MICROINVENTORY/ EMPIRICAL MODEL
SHORT-TERM SAMPLING
MICROSCOPY
RACT
EXTRA-REGIONAL OR LOCAL SOURCES TABLE 28
CHARACTERIZATION OF LOCAL SOURCES TABLE 29
CONFIDENCE IN RESULTS TABLES 29-30
CONCLUSIONS

Figure 11. Process used to synthesize analysis techniques.

TABLE 28. EXTRA-REGIONAL OR LOCAL PARTICULATE SOURCES

Site	Analytical technique				
	Statistical analysis	Microinventory/empirical model		Short-term sampling	Microscopy
Eighth and Edmond	Urban pattern, first quarter peak Correlation of 0.92 with Belt and Frederick site Concentration rose suggests urban influence Violations most likely with winds from north or south 5-year measured concentration is 88 $\mu g/m^3$	 Background and unexplained Area and local Point Predicted concentration is 88 $\mu g/m^3$	Cont.[a],% 65 35 0.2	Based on statistically invalid sample, measured concentration is 88 $\mu g/m^3$ <2.5 μm fraction = 10 $\mu g/m^3$	Sulfates, nitrates 7-16 $\mu g/m^3$
Lake Road Sewage Treatment Plant	Rural pattern, third quarter peak Poor correlation, all sites Concentration rose suggests urban influence Violation most likely with winds from 0-180° 4-year measured concentration is 81 $\mu g/m^3$	 Background and unexplained Area and local Point Predicted concentration is 83 $\mu g/m^3$	Cont.,% 69 24 7	Based in statistically invalid sample, measured concentration is 91 $\mu g/m^3$	Sulfates, nitrates 9-20 $\mu g/m^3$
Belt and Frederick	Urban pattern, first quarter peak Correlation of 0.92 with Eighth and Edmond site Concentration rose suggests urban influence Violations most likely with winds from 180-360°	b		b	b
Rosecrans Airport	b	 Background and unexplained Area and local Point Predicted concentration is 59 $\mu g/m^3$	Cont.,% 98 2 0	Based on stastitically invalid sample, measured concentration is 77 $\mu g/m^3$ <2.5 μm fraction = 7 $\mu g/m^3$	Sulfates, nitrates 13-34 $\mu g/m^3$
Fire Station	b	 Background and unexplained Area and local Point Predicted concentration is 79 $\mu g/m^3$	Cont.,% 73 27 0	Based on statistically invalid sample, measured concentration is 75 $\mu g/m^3$	Sulfates, nitrates 6-21 $\mu g/m^3$
Faraon Street Sewage Treatment Plant	b	 Background and unexplained Area and local Point Predicted concentration is 59 $\mu g/m^3$	Cont.,% 97 3 0	Based on statistically invalid sample, measured concentration is 62 $\mu g/m^3$	Sulfates, nitrates 5-15 $\mu g/m^3$
Kansas City International Airport	Rural pattern, third quarter peak Poor correlation, all sites Concentrations highest with winds from east and southeast 6-year measured concentration is 48 $\mu g/m^3$				

[a] Contribution, percent of total suspended particulate.

[b] Data not available.

TABLE 29. CHARACTERIZATION OF ST. JOSEPH PARTICULATE SOURCES

	Analytical technique				
	Statistical analysis	Microinventory/ empirical model	Short-term sampling	Microscopy	RACT
Eighth and Edmond	Suggests urban sources, particularly traffic	St. Joseph sources μg/m^3 Traffic related 27.3 Industrial process 2.3 Point 0.2 Other 1.1 Total 30.9	Reinforces results from model and microscopy	St. Joseph sources Cont.,%[a] Traffic, construction, agriculture, exposed 36-76 Point, Ind. process 2-11 Grain handling 3-17 Other 2-4	RACT on Quaker Oats would reduce concentrations 0.1 μg/m^3 (empirical model)
Lake Road STP	Suggests urban and rural sources	St. Joseph sources μg/m^3 Industrial process 10.7 Exposed areas 7.8 Point 6.0 Traffic related 1.6 Other 0.1 Total 26.2	Reinforces results from empirical model and microscopy	St. Joseph sources Cont.,% Traffic, construction, agriculture, exposed 55-73 Point, ind., process 2-15 Grain handling 1 Other 6-7	RACT on St. Joseph P&L would reduce concentrations 2.5 μg/m^3 when burning coal (empirical model)
Belt and Frederick	Suggests urban sources, particularly traffic	b	b	b	b
Rosecrans Airport	b	St. Joseph sources μg/m^3 Aircraft 0.2 Traffic related 0.5 Exposed areas 0.4 Agriculture 0.3 Total 1.4	Data incompatible with microinventory results. Suggests additional local or long-range transport sources	St. Joseph sources Cont.,% Traffic, construction, agriculture, exposed 41-75 Point, ind. process 1-7 Grain handling 5-9 Other 4-6	
Fire Station	b	St. Joseph sources μg/m^3 Traffic related 20.4 Construction 0.7 Other 0.5 Total 21.6	Reinforces results from empirical model and microscopy	St. Joseph sources Cont.,% Traffic, construction agriculture, exposed 61-70 Point, ind. process 4-8 Grain handling 3-2 Other 4-8	
Faraon Street STP	b	St. Joseph sources μg/m^3 Exposed areas 1.0 Agriculture 0.8 Other 0.1 Total 1.9	Reinforces results from empirical model and microscopy	St. Joseph sources Cont.,% Traffic, construction, agriculture, exposed 45-73 Point, ind. process 2-9 Grain handling 5-13 Other 4-9	
Kansas City International Airport	Suggests agriculture sources	b	b	b	b

[a] Contribution, percent of total suspended particulate.
[b] Data not available.

Microinventory/Empirical Model--

Microinventories located significant particulate sources within 1 mile of the Eighth and Edmond, Lake Road Sewage Treatment Plant, and Fire Station sites. Based on the empirical model, these sources are estimated to contribute 35, 24, and 27 percent, respectively, of the total concentration. Point sources significantly influence concentrations at the Lake Road STP and slightly influence concentrations at the Eighth and Edmond site. Conversely, a relatively high background concentration of 43 $\mu g/m^3$ is evidence of a large quantity of particulate in the air not directly attributable to known sources.

Short-Term Sampling--

Although caution is required when interpreting the short-term data, it appears that the TSP nonattainment area may be larger than originally anticipated based on data from new monitoring sites (Fire Station and Rosecrans Airport). However, local sources around the Rosecrans site causing measured values of 77 $\mu g/m^3$ could not be identified. This suggests a large extra-regional contribution or the presence of local sources that have not been identified. The particle size data generated suggests an extra-regional contribution of 2 to 31 $\mu g/m^3$ based on the <2.5 µm fraction. Differences were seen between the particulate levels observed at the SLAMS monitoring sites and levels observed at co-located short-term sampling sites.

Microscopy--

Sulfates and nitrates found on the filters are probably indicative of long-range transport of fuel combustion emissions (see page D-8). Sulfate/nitrate concentrations were found to range from 3 to 41 percent of the mass, representing a concentration of 5 to 34 $\mu g/m^3$. Excluding data from the Rosecrans site, which was significantly higher, the range in sulfate/nitrate values from the other sites was fairly uniform and ranged from 5 to 21 $\mu g/m^3$. A small portion of the mineral material may also be attributable to extra-regional sources. Other material identified on the filters was directly attributable to local sources at all five sites.

Synthesis--

Three factors suggest that a portion of the TSP concentrations found in St. Joseph can be attributed to extra-regional sources. These are the high background level (statistical analysis), the less than 2.5 µm particle size fraction ranging from 2 to 31 $\mu g/m^3$ (short-term sampling), and the presence of sulfate/nitrate material on the filters equivalent to 5 to 34 $\mu g/m^3$ (microscopy). In addition to these factors indicating that a portion of the concentration is due to extra-regional sources, all five analytical techniques indicate some impact from local sources. At the Eighth and Edmond, Lake Road STP, and the Fire

Station, the data indicate that at least 24 to 35 percent of the concentration is locally generated.

Short-term TSP monitoring data from the Rosecrans Airport site are incompatible with the microinventory/empirical model results. The measured concentrations exceed the level predicted by the empirical model by 16 μg/m³.

Short-term particle size sampling suggests some extra-regional contribution at the Rosecrans Airport site, with the <2.5 μm fraction ranging from 2 to 31 μg/m³. The microscopy results also indicate an extra-regional contribution, with sulfate/nitrate levels ranging from 13 to 34 μg/m³. Conversely, the microscopy data also indicate local sources including traffic, agriculture, and industrial sources.

In contrasting the Rosecrans Airport and Lake Road STP microscopy results, sulfate/nitrate contributions at the Lake Road site were 9 to 20 μg/m³, or somewhat lower than the Rosecrans Airport values. If the sulfate/nitrate contributions at the Rosecrans Airport site were a result of long-range transport, the values for the two sites would be very similar; they are not. Two explanations for the disparity are possible. The sulfate/ nitrate contribution may be similar and the descrepancy was caused by the samples selected for analysis or the analysis technique. The second possible explanation is that a local source is causing the formation of secondary combustion material upwind of the Rosecrans Airport site. The high measured short-term TSP value at the Rosecrans site is the greatest data inconsistency in the study.

The short-term monitoring suggests there may be a systematic sampling bias increasing measured values above actual values. This finding warrants additional research.

Characterization of St. Joseph Area Sources

Statistical Analysis--

The statistical analysis provides only limited insight into the nature of local sources other than to suggest the existence of urban sources, particularly at the Eighth and Edmond and the Belt and Frederick site.

Microinventory/Empirical Model--

This technique allows direct identification of contributing sources within the bounds of model accuracy. At the Eighth and Edmond site, at least 31 μg/m³ of the predicted concentration of 88 μg/m³ was attributable to St. Joseph sources. Of the St. Joseph sources, about 29 μg/m³ was traffic related. The Lake Road STP results show that 26 μg/m³ of the predicted concentration of 83 μg/m³ was attributable to St. Joseph sources consisting of industrial process, point sources, and exposed areas. At the

Fire Station site, traffic sources contributed 20.4 μg/m^3 of the predicted concentration of 79 μg/m^3. The Rosecrans and Faraon STP sites showed only limited influences from local sources.

Short-Term Sampling--

The short-term TSP sampling results are inconclusive except in their relationship to microinventory/empirical model and microscopy results. The relationship is discussed in the synthesis below. The dichotomous sampling was also inconclusive with regard to the characterization of local sources.

Microscopy--

The microscopy results point to the same sources identified in the microinventory/empirical model approach but tend to indicate a higher percentage of local contribution. Resuspended dust from traffic, agriculture and/or construction, and exposed areas are the principal categories at all sites. Unlike the microinventory/empirical model results, some point source and grain handling emissions were shown to impact all monitors.

RACT--

The analysis tentatively indicates that only two monitors would be impacted by application of RACT to all major point sources. Concentrations would decrease by about 2.5 μg/m^3 with RACT controls on St. Joseph Power & Light when the power plant was burning coal. Concentrations would decrease slightly at the Eighth and Edmond site with RACT applied to the Quaker Oats facility. These conclusions are based on the microinventory/empirical model approach. If point sources contribute to a greater extent, as suggested by the microscopy results, the impact of RACT controls would be greater.

Synthesis--

The microinventory/empirical model and microscopy were the two most useful techniques in identifying local sources. Both techniques point to the same sources, although the microscopy results show a stronger local source contribution to TSP. Of the local sources, the Eighth and Edmond and Fire Station sites are heavily impacted by reentrained dust from streets and automobile emissions. The Eighth and Edmond site is also impacted by industrial process and point source emissions. The Lake Road STP site is impacted by St. Joseph area industrial process, exposed area, and point source emissions, with a lesser contribution from traffic sources. The Faraon Street site is only slightly impacted by local sources, although the microscopy results suggest a higher local source impact than the microinventory/empirical model. Data from the Rosecrans Airport site was problematical, as discussed in the synthesis for the first question. The microinventory delineated few local sources. The microscopy results and particularly the short-term sampling results suggest the presence of some local source impact.

CONFIDENCE IN RESULTS

No statistical approach is available to quantify the confidence level of the results of the five analysis techniques. Lacking such a methodology, the results of the analysis techniques are compared in Tables 30 and 31. Table 30 contains a comparison of numerical values generated by the individual analysis techniques. Table 31 contains a comparison of conclusions suggested by the individual analysis techniques.

The first four comparisons in Table 30 relate microscopy results to other techniques. In the first comparison, particle size data are roughly comparable by the two methods. The second comparison shows agreement within the range of accuracy of the two techniques. Correlation between the data sets was high. The third comparison indicates a greater influence of biological material according to microscopy than according to the microinventory/empirical model approach. The biological material found suggests grain handling or agricultural crop processing. However, the material on the filters also included pollen, plant hairs and fragments, and insect parts, although the amounts are not enough to explain the total difference. The fourth comparison indicates a larger contribution of rubber tire fragments by microscopy than by microinventory. This may be a function of the emission factor used in the microinventory or particle misidentification in the microscopy technique. The contribution from this source is small in any event.

The fifth comparison is between measured and predicted values. The Eighth and Edmond, Fire Station, and Faraon Street STP values are within 4 $\mu g/m^3$. The Lake Road historical data are within 2 $\mu g/m^3$ of the predicted value from the empirical model, but 8 $\mu g/m^3$ different than the short-term sampling. The higher mean concentration from the short-term sampling is probably the atypical value of the three. The higher value is probably due to the extensive grain handling/processing and the lack of moisture during the sampling period. There is a wide disparity of values for the Rosecrans Airport site. This has been discussed previously and no cause has been found.

Table 31 presents a comparison of conclusions suggested by the individual analysis techniques. Considering the range of techniques, the agreement is excellant. With regard to the first hypothesis, all five techniques pointed to the existence of local sources. There was also a high level of agreement on the characterization of St. Joseph area sources, with the exception of the Rosecrans Airport data. The lower concentration of 62 $\mu g/m^3$ recorded at the Faraon Street site suggests that an unidentified St. Joseph area source is responsible for the Rosecrans Airport concentration, as opposed to long-range transport.

TABLE 30. COMPARISON OF NUMERICAL VALUES GENERATED BY INDIVIDUAL ANALYSIS TECHNIQUES

	Statistical analysis (historical TSP data)	Microinventory/ empirical model	Short-term sampling	Microscopy
1. Particle size			<15 μm = 48% of TSP concentration	Mass mean particle size of 12-14 μm (aerodynamic), or <13 μm = 50% of TSP
2. Comparison of RP (fine fraction) and sulfate/ nitrate			RP range = 2-31 $\mu g/m^3$ Mean = 8.6 $\mu g/m^3$ Correlation of 0.91 with microscopy	Sulfate/nitrate ranges 5-34 $\mu g/m^3$ Mean = 12.5 $\mu g/m^3$
3. Presence of grain sources		Grain sources at Lake Road STP only		Grain sources (biological matter) at all sites
4. Vehicle emissions (exhaust and tire wear)		0-3 $\mu g/m^3$		1-12 $\mu g/m^3$ Mean = 4.3 $\mu g/m^3$
5. Comparison of measured and predicted values $\mu g/m^3$				
Eighth and Edmond	85	88	88	
Lake Road STP	81	83	91	
Rosecrans Airport		59	77	
Fire Station		79	75	
Faraon Sreet STP		59	62	

TABLE 31. COMPARISON OF CONCLUSIONS SUGGESTED BY INDIVIDUAL ANALYSIS TECHNIQUES

Hypothesis	Statistical analysis									
	Seasonal conc.	Daily conc.	Intersite correlation.	Pollution rose	Regression/ correlation	Meteorological	Microinventory/ empirical model	Short-term sampling	Microscopy	RACT
1. A portion of the TSP concentration in the St. Joseph area is due to local sources	++	++	++	++	°	°	++	+	++	+
2. Local sources are: (in order of importance)										
Eighth and Edmonds										
Traffic										
Industrial process	++	°	++	+	°	°	+	++	++	+
Point										
Lake Road STP										
Industrial process										
Exposed areas	++	°	++	+	°	°	++	++	++	+
Point										
Traffic										
Belt and Frederick										
Traffic	++	++	++	++	°	°				
Rosecrans Airport										
Few local sources							++	-	°	°
Fire Station										
Traffic							++	++	+	°
Construction										
Faraon Street STP										
Few local sources							++	++	+	°

++ Strongly supports. + Supports. ° Not conclusive. - Does not support.

APPENDIX A

MICROINVENTORY PROCEDURES

The microinventory technique described herein was developed over the past 4 years as part of the particulate analyses in several regional areas. The procedures followed are not necessarily technically superior to alternative methods that might be used. They have evolved as a result of this past experience, however, and are recommended for succeeding inventories, primarily to maintain consistency in data collection and to minimize the time required in the field.

The survey procedure employed was to ground survey, via automobile, the sampler stations and all probable sources of emissions within a 1-mile radius of each sampling site. This method enabled the survey team to make the best observation of overall site exposure and to identify the sources with primary impact on the samplers. The 1-mile radius around each sampler was specified because that is approximately the range to which theoretical treatments (dispersion modeling) show that low-level sources will have a significant impact.

Sources of fugitive dust and conventional point and area sources were located on maps during the ground survey and labeled with pertinent data such as size and boundaries, observed activity and operational characteristics, and estimated emission rates. Two observers independently estimated and agreed upon parameters observed at each site to increase accuracy and completeness.

PREPARATORY WORK

Point source and air quality data were obtained from the State air pollution control agency. Traffic volume maps were obtained from the State and local traffic departments. Two other types of maps were also utilized during the microinventories. USGS 7-1/2 minute quadrangle maps were used to locate sampler sites and point sources by UTM coordinates. They were also a convenient size and scale (1 in. = 2000 ft) for covering the impact area--1-mile radius for area sources and a 5-mile radius for point sources. A city street map was used for planning and navigating the survey route.

A 1-mile radius was drawn on the USGS map for each site, and the major streets were identified thereon. Copies of each of these maps were made for field use. A separate sketch of the 1/4-mile radius area was drawn to scale (1 in. = 400 ft) to provide even greater detail for the area close to the sampler. An alternative to the 1/4-mile radius sketch would have been to mark information directly on an aerial photo for each site.

FIELD WORK

The actual inventory procedure followed was to begin at the sampler site and survey the 1/4-mile radius area first. Photographs were taken of the sampler location. Monitor height and placement were recorded on an auxiliary data sheet. Any physical interference that could bias the air quality readings was also noted. The site code (if available), street address, and distances of the nearest intersecting streets or localized sources were determined and recorded.

The field team then observed each street within the 1/4-mile radius and noted the location of all the pertinent sources on the sketch. Closer inspections of the sources were made as necessary. All important parameters were independently estimated and then agreed upon by the two observers. For area sources, the type, dimensions, and activity rate were recorded. For point sources, the company name, source types, and estimated stack heights were noted. This information was usually recorded on an auxiliary data sheet.

The general condition of paved streets within the area was described on the 1/4-mile sketch by indicating whether streets were curbed or uncurbed. Surface conditions and dirt loadings were described as clean or dirty.

The above steps were repeated with little modification for the rest of the 1-mile radius survey area. In many cases, it was possible to inventory this area by driving across alternate streets, in a cross hatch pattern, covering each zone completely. In this way, all intersections and sources were observed from a maximum one-block distance. Locations of point and area sources were shown on copies of the USGS map or, where available, on aerial photo maps; descriptions of the sources were recorded on the data sheets.

Topography

The topography of each survey area was briefly characterized. Since the purpose was to account for any increase in concentrations that might occur as a result of pollutant trapping or for any decrease that might occur as a result of an elevated sampler, the topography description was primarily concerned with sampler placement rather than the surrounding land area. In order to keep this element of the model as simple as possible, only two descriptors were used:

1. Elevated receptor

2. No special terrain

Measuring Distances of Sources

For purposes of determining the distance from a source to the sampler, the following rules were observed:

Within 200 ft of the monitor - determine distance to ±5 percent during initial visit to the site

From 200 ft to 1/4 mile - scale off the aerial photo map

From 1/4 to 1 mile - scale off either the aerial photo map or the USGS map

Distances to sources within 200 ft of the monitor were recorded during the survey. Distances beyond 200 ft were scaled from a map and recorded on the data sheet at a later date following completion of the field work.

Defining Sources

So that all inventories were done with the same degree of detail, it was necessary to establish exactly what sources were to be included. If a stack emission appeared to involve an industrial process not included in the point source listing, the source was noted if the facility appeared to be operating at the time of the survey.

Defining what constitutes a fugitive dust source was somewhat more difficult; however, sources of fugitive dust would include at least the following activities:

excavating
grading
detonation of explosives
earth moving
construction
demolition
site preparation
sand blasting
mining
quarrying
handling and transporting of materials
barren storage areas or storage piles
vehicle movement (reentrainment)
unpaved roads
unpaved parking lots
agricultural tilling
wind erosion of exposed surfaces

processing of sand, gravel, and rock
crushing
screening
drying
feedlots
campgrounds
fairgrounds
playgrounds
athletic fields

Unpaved driveways or unpaved road shoulders were not included unless they were common to all the blocks in a particular segment. The presence of these sources often resulted in increased street dirt loadings, however, and those streets were noted to be dirty.

A significant factor in determining which temporary sources to consider is the time period for which the source is expected to be active. For example, a construction site should be included as a fugitive dust source only if the air quality data are for the period of time the site is active.

A checklist for the procedures discussed above is presented in Table A-1. This list should facilitate both the planning and the execution of the field surveys so that consistent data collection is achieved for succeeding microinventories.

TABLE A-1. CHECKLIST OF STEPS IN MICROINVENTORY

Presurvey and preparatory work

1. Identify sampling sites to be inventoried: record SAROAD code and street address
2. Determine distances to localized sources within 200 feet and sampler height (obtained during site tour)
3. Note possible interferences of biases (obtained during site tour)
4. Take photographs of site and surrounding area (obtained during site tour)
5. Obtain U.S. Geological Survey maps of the area (from either USGS or a local engineering supply store)
6. Obtain traffic data (from local COG, or city or state transportation agency)
7. Obtain recent air quality data (local or state air pollution control agency)
8. Obtain gridded inventory of area source emissions (local agency)
9. Obtain point source inventory including annual particulate emissions and UTM coordinates (local agency)
10. Obtain aerial photographs (from local COG or city engineering department)
11. Prepare maps for field survey (USGS maps and 1/4-mile sketches)

Field work

1. Describe topography around sampler
2. Survey 1/4-mile area: locate all sources on 1/4-mile sketch, describe on data sheet
3. Note condition of streets
4. Survey remainder of one-mile radius area: locate sources on copy of USGS map, describe on same data sheet as above

Calculations

1. Allocate area source emissions (from agency inventory) to one-mile radius area and to subareas
2. Calculate emissions for discrete fugitive dust sources; assign to appropriate sectors
3. Calculate vehicle-related emissions by sector
4. Prepare table of point source data by increasing distance from site
5. Compare listing with point sources identified in field; add to list any sources missed
6. Add small point sources (less than 25 tons/yr) as an area source category

APPENDIX B

DEVELOPMENT OF EMISSION FACTORS

RAILROAD YARDS

Most of the emissions in train yards appear to be from wind erosion rather than from train movement. Therefore, an adaptation of the U.S. Department of Agriculture's wind erosion equation was used as the basis for deriving emission factors for railroad yards. The modified equation estimates annual suspended particulate emissions due to wind erosion from exposed soil surfaces:[1]

$$E = a\ I\ K\ C\ L'\ V' \qquad \text{(Eq. 1)}$$

where E = emission factor, ton/acre per year

a = portion of total wind erosion losses that would be measured as suspended particulate, estimated to be 0.025

I = soil erodibility, ton/acre per year

K = surface roughness factor

C = climatic factor

L' = unsheltered field width factor

V' = vegetative cover factor

In this equation, K, C, L', and V' are all dimensionless. An average erodibility (I) of 56 tons/acre per year was assumed to be applicable for the soil in the railroad yards. The area around railroad yards generally has a fairly smooth surface, which is equivalent to a K value of 1.0. The climatic factor for the St. Joseph area is 0.1. An average width of 1000 ft was assumed for railroad yards, since this is not a critical variable in the equation. The L' value equivalent to L = 1000 ft was determined from a nomograph in which soil type is also a variable--0.60. Because there is no vegetation in rail yards, V = 0 and V' = 1.0. Also, these areas are generally treated with oil or chemicals to reduce dust and weed problems. Therefore, the emissions have been estimated based on the above values and the following assumptions:

- no vegetation

- half the area is stabilized, with an emission rate cf 20 percent of the unstabilized area

- train traffic increases the wind erosion emissions by 20 percent

Thus, the resulting emission factor is as follows:

$$E = (0.025)(56)(1.0)(0.1)\ (0.60)(1.0)\left(\frac{1 + 0.2}{2}\right)(1.2)$$

$$= 0.06 \text{ ton/acre per year}$$

REENTRAINED DUST FROM PAVED STREETS

The most recent emission factors for estimating emissions from paved roads were obtained from a draft of AP-42. The recommended emission factors are 5.6 g/VMT for clean streets and 20.5 g/VMT for commerical streets. These factors include an exhaust and tire wear emission factor and are not corrected for days with rain.

Based on national estimates for the percentage of heavy duty gasoline and diesel trucks, an exhaust and tire wear emission factor of 0.6 g/VMT for clean streets and 1.2 g/VMT for commercial streets was calculated from published emission factor data.[2] This factor was subtracted from the paved road emission factors, and the resulting values were corrected for rainfall.

Historical rainfall data for St. Joseph indicate a mean of 100 days with at least 0.01 in. of rain.[3] Based on this information, the reentrained dust emission factors were reduced by approximately 27 percent. Street sanding has the opposite effect on emissions as does rainfall and tends to increase the emission factor slightly. The assumptions have been made that there are 17 street sanding operations per year in the St. Joseph area and that the emission rate is doubled for two days after sanding. The final corrected emission factors are as follows: 3.9 g/VMT for clean streets and 16.9 g/VMT for commercial streets.

UNPAVED ROADS

Many different groups have investigated emissions from unpaved roads. All the studies show emission rates usually in the range of 1 to 20 lb/VMT, and show that the rate is highly dependent on vehicle speed. After reviewing these studies, EPA selected the following emission factor for publication in AP-42:[2]

$$E = (0.6)(0.81)(s)(S/30)\left(\frac{365 - w}{365}\right) \qquad \text{(Eq. 2)}$$

where E = emission factor, lb/VMT

0.6 = fraction of total particulate less than 30 u diameter

s = percent silt of road surface material

S = average vehicle speed, mph

w = mean annual number of days with 0.01 in. or more of rainfall

The percent silt on gravel road surfaces is about 12 percent based on data presented in the EPA publication, Development of Emission Factors for Fugitive Dust Sources.[1] No aggregate material is applied to the road bed of graded and drained road surfaces. It is composed of compacted native soil. The fine material originally on the surface is probably rapidly removed by turbulence from passing vehicles or by wind and water erosion forces. The remaining stable surface is composed of sand- and pebble-sized particles; dust is generated primarily by the continuing mechanical breakdown of these particles as a result of traffic. It is assumed that the percent of silt-sized particles on a seasoned dirt road surface is approximately the same as that for gravel, or 12 percent. The mean number of days with 0.01 in. or more of rainfall is 100. Assuming a vehicle speed of 20 mph, the average emission factor is 2.8 lb/VMT.

CLEAR OR EXPOSED AREAS

The modified wind erosion equation described earlier was used for estimating emissions from cleared or exposed areas. An average erodibility (I) of 56 tons/acre per year was assumed for the soil types common to this area. The cleared areas are generally left with a fairly smooth surface, which is equivalent to a K value of 1.0. The climatic factor for the St. Joseph area is 0.1. An average field width of 1000 ft was assumed for all the cleared areas, since this is not a critical variable in the equation. The L' value equivalent to L = 1000 ft was determined from a nomograph in which soil type is also a variable--0.60. Because there is no vegetation on cleared areas, V = 0 and V' = 1.0.

Based on these input data, the average emission rate from cleared areas would be 0.11 ton/acre per year.

CONSTRUCTION

The emission factor presented in AP-42 of 1.2 ton/acre per month is corrected for the climatic conditions in St. Joseph by use of the equation:[1]

$$E = \frac{1.2}{(PE/50)^2} \qquad \text{(Eq. 3)}$$

where PE = 96 for St. Joseph

$E = 0.33$ ton/acre per month

This value is appropriate for residential and commercial construction with excavation and regrading, and includes the effect on emission reduction of moderate watering of the site. Construction projects are assumed to be fugitive dust sources for 3 months a year if they are residential and 6 months a year if commercial or industrial.

AGRICULTURE

Total emissions from agriculture are calculated from the sum of tilling and wind erosion emissions. The factor for tilling from AP-42 is as follows:[2]

$$E = (0.8)(1.4)s/(PE/50)^2 \qquad \text{(Eq. 4)}$$

where E = emission factor, lb/acre per run

0.8 = fraction of total particulate less than 30 u diameter

s = percent silt in surface soil

PE = precipitation-evaporation index

An average of three tilling operations per year is assumed along with a silt content of 40 percent. Therefore, total tilling losses are 0.08 ton/acre per year.

The modified wind erosion equation described earlier is recommended for determining the wind erosion component of agricultural emissions. All variables in the equation except C are dependent on either the soil type or crop grown on each field. The following average values were assumed for the St. Joseph area:

$I = 56$

K = 0.6 corn, soybeans

= 0.5 milo

C = 0.1

L = 2000 ft, L' = 0.75 corn, soybeans, milo

V (corn) = 500 lb/acre, V' = 0.15

V (soybeans) = 250 lb/acre, V' = 0.63

V (milo) = 900 lb/acre, V' = 0.02

E (corn) = 0.009

E (soybeans = 0.040

E (milo) = 0.001

Therefore, the combined agricultural losses are 0.027 ton/acre per year for corn, 0.058 ton/acre per year for soybeans, and 0.019 ton/acre per year for milo.

UNPAVED PARKING LOTS

If the average number of vehicles using a parking lot daily and the average distance of travel in the lot can be estimated, these data can be converted to VMT/yr and then multiplied by the emission factor for unpaved roads to determine unpaved parking lot emissions. With an average speed of 10 mph in the parking lots, the emission factor is 1.4 lb/VMT.

UNPAVED STORAGE AREAS

No factor was found for this source category. By comparison with other source categories, it was estimated that annual emissions per acre from this source were greater than for a cleared area (0.112 ton/acre per year) or railroad yards (0.1), but not nearly as high as construction (0.33). A value of 0.2 ton/acre per year was used for this source category.

CATTLE FEEDLOTS

In determining the emission factor for feedlots, the number of cattle present in the specific lot in question is normally used. In this investigation, only the size of the feedlot was determined. Since only the feedlot area was ascertained, a factor of 3 tons/acre per year was used as an emission factor.[4]

GRAIN ELEVATORS

A value of 1.8 tons/silo per year was developed from file data for a previous PEDCo study of particulate air quality in rural Kansas and Nebraska.[5] This same value was applied here for sources for which NEDS data were not available.

INCINERATORS

The emission factor presented in AP-42 of 7.0 lb/ton of refuse burned was used to calculate emissions from this source.

REFERENCES

1. Development of Emission Factors for Fugitive Dust Sources. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication Number EPA 450/3-74-037. June 1974.

2. Compilation of Air Pollutant Emission Factors. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication Number AP-42. August 1977.

3. Local Climatological Data, Annual Summary with Comparative Data. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Center, Ashville, North Carolina. 1976.

4. Investigation of Fugitive Dust - Sources, Emissions, and Control. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. May 1973.

5. Fugitive Dust in Kansas and Nebraska. PEDCo Environmental Specialists, Inc., Cincinnati, Ohio. Prepared for U.S. Environmental Protection Agency. February 1974.

APPENDIX C

DESCRIPTION OF EMPIRICAL PARTICULATE MODEL

The empirical particulate model represents a new approach to quantifying the relationship between particulate emissions and ambient concentrations. It was developed primarily by Tompson G. Pace of EPA, Office of Air Quality Planning and Standards, and is based on the correlation previously observed between measured particulate concentrations and emission density within a 1-mile radius surrounding the sampler. The technique for inventorying particulate sources within this area has evolved to its present state over a period of about 5 years. The technique, commonly referred to as a microinventory, is described in detail in several publications and will not be repeated here.

FORM OF EMPIRICAL MODEL

The form of the model is a multiple linear regression equation with annual geometric mean particulate concentration as the dependent variable and seven independent variable terms. The independent variables are annual area source emissions within 1 mile, annual point source emissions within 5 miles, local sources (particularly traffic-related), presence of dirt on the nearest street, and three city-specific adjustments to the background concentration. These variables were determined by screening approximately 30 potential variables by simple linear regression and selecting the independent ones with the highest partial correlations. Stepwise multiple regression was then employed to derive the coefficients for each of the terms in the equation and to obtain the statistical values used to judge the accuracy of the regression equation.

The data base for developing the model was generated at 79 sites in four cities which each had measured concentrations, microinventory results, and other information such as surrounding land use and distances to the sources. The multiple correlation (r) with the seven variables was 0.876, based on the use of all 79 data sets; none was eliminated as outliers. Therefore, the seven variables explained 0.767 of the variance (r^2) in measured concentrations.

The resulting general equation is as follows:

$$\text{AVGAQ} = 0.00451(\text{AREA}) + 0.00096(\text{POINT}) + 50.5(\text{LOCAL}) + 18.6(\text{VISDT}) + (\text{DPT, DSL, DB, or } 0) + 57.2$$

where AVGAQ = Predicted annual geometric mean, $\mu g/m^3$

$$\text{AREA} = \frac{A_1}{0.0324} \quad \frac{25}{\text{HGT}} \;++\; \frac{A_2}{0.16} + \frac{A_3}{0.6084}$$

A_i = Total area source emissions in zone i, ton/yr (zone locations are shown in Figure 1)

HGT = Height of sampler, ft

$$\text{POINT} = \sum_{i-1}^{n} \frac{\text{PSEM}_i}{D_i^{\,2}} (\text{WWF})$$

n = Number of point sources within 5 mi

PSEM_i = Emissions from point source i, ton/yr

D_i = Distance to point source i, mi (lower limit of D_i if 0.25)

WWF = Wind weighting factor, computed as wind frequency (%) in quadrant where source is located divided by 25, dimensionless

$$\text{LOCAL} = \frac{\ln \text{ADT}_1}{\sqrt{\text{HGT}^2 + \text{DIS}_1^{\,2}}} + \frac{\ln \text{ADT}_2}{\sqrt{\text{HGT}^2 + \text{DIS}_2^{\,2}}}$$

ADT_i = Average daily traffic on nearby road i, veh/day

DIS_i = Distance to road i, ft (upper limit of DIS_i is 200)

VISDT = 0 if no visible plume results from passing traffic, 1 if there is a plume

DPT, DSL, DB = Dummy variables to account for different background concentrations in each of the cities relative to Kansas City:
DPT = -21.6 (Portland), DSL = -6.6 (St. Louis),
DB = -6.9 (Birmingham)

Corresponding multiple regression equations with different coefficients and only four variables can be developed by using the samller data set from any one city. For example, the equation derived with just the 32 Kansas City sites would be:

$$\mathrm{AVGKC} = 0.0054(\mathrm{AREA}) + 0.00057(\mathrm{POINT}) + 55.2(\mathrm{LOCAL}) + 10.6(\mathrm{VISDT}) + 57.6$$

The equation using the 23 St. Louis sites would be:

$$\mathrm{AVGSL} = 0.0019(\mathrm{AREA}) + 0.0020(\mathrm{POINT}) + 45.9(\mathrm{LOCAL}) + 25.0(\mathrm{VISDT}) + 56.0$$

EVALUATION OF MODEL

Three independent evaluations of the model were performed: one from the statistics provided by the stepwise multiple regression program, the second by testing the model's predictions with data from 34 additional sites in three other cities.

The summary statistics from the stepwise multiple regression analysis with 79 data sets are presented in Table C-1. Prior to the regression analysis, a correlation matrix was prepared to determine whether intercorrelations between any of the variables could bias the results. The variables were all found to be independent. In testing the individual variables to determine whether each was significant, the F test was used. The critical F value of 2.87 at the 99 percent level for seven variables and 79 observations, compared with the F values in Table C-1, indicated that all the variables except the city-specific adjustments to background were highly significant.

The standard errors for the variable coefficients were, again with the exception of the city-specific variables, only about 20 percent of the coefficient values. The standard error of the regression equation was 13.6 $\mu g/m^3$, about 17 percent of the average measured concentration. The relative errors for all but 3 of the 79 predicted concentrations were less than 28 percent. It should be emphasized again that none of the data sets from the four cities was removed before performing the regression analysis, although some were suspected to contain anomalies.

The stability of sensitivity of coefficients in the equation was tested by running two additional regression analyses, each with 75 percent of the sites (selected at random) from the initial analysis. The AREA and POINT coefficients were found to be very stable, the LOCAL coefficient fairly stable, and the VISDT coefficient farily sensitive to the specific sites included and excluded. It was determined that a few influential sites could affect the VISDT coefficient by as much as 15 percent.

TABLE C-1. SUMMARY OF STEPWISE MULTIPLE REGRESSION ANALYSIS

Variable[a]	Multiple correlation[b]	Regression coefficient	Std error of regression coefficient	Computed F value	Cumulative proportion of sum of squares reduced (r^2)
AREA	0.617	0.00451	0.00082	30.4	0.381
POINT	0.761	0.00096	0.00014	45.7	0.579
DPT	0.813	-21.6	4.9	18.9	0.660
LOCAL	0.838	50.5	12.0	17.6	0.703
VISDT	0.869	18.6	4.9	14.6	0.756
DSL	0.873	-6.6	4.0	2.8	0.761
DB	0.876	-6.9	5.4	1.7	0.767
Intercept		57.2			

[a] In order of selection by regression program.
[b] Adjusted for degrees of freedom.

Comparison of model-predicted and measured concentrations at 34 additional sites in three cities showed that, with consideration of city-specific background concentrations, the predicted values were quite good:

City	No. of sites	r	r^2	Slope	Intercept
Philadelphia	10	0.95	0.90	1.16	-12.7
Pittsburgh	8				
Boston-Worchester	11	0.93	0.86	1.03	-6.5

If the linear regression for a particular area yields a good correlation but the model consistently over- or under-predicts concentrations, the accuracy of the predictions can be improved by calculating the variable (e.g., DPT, DSL, DB) for the area being analyzed.

This variable is simply the average residual for the samplers in the study area. The average residual is readily computed with the equation:

$$R = \sum_{i=1}^{n} \frac{MC_i - PC_i}{n}$$

where R = average residual

MC_i = measured concentration at site i, $\mu g/m^3$

PC_i = predicted concentration at site i, $\mu g/m^3$

n = number of samplers

The average residual is, effectively, a correction to the 57.2 constant term in the general form of the empirical model.

APPLICATION OF MODEL

The empirical model is only moderately data intensive. It can be used for particulate air quality analyses ranging from neighborhood to regional scales. The primary purpose of the model is to estimate the relative impacts of different sources and source categories on ambient concentrations. It cannot properly be used to predict concentrations at specified locations in areas other than those for which it is specifically developed, because of its means of derivation and the magnitude of the standard error associated with the regression equation. It is very useful in interpreting microinventory data by estimating the relative impacts of various sources and source categories at specific sites in other areas.

At each site, the measured concentration provides a check on the accuracy of the model's prediction. The only limitation to this self-validating feature is that several sites in a city must be microinventoried to obtain the city-specific background adjustment before the model can yield its best prediction.

APPENDIX D

MICROSCOPICAL ANALYSIS OF ST. JOSEPH TSP

IIT Research Institute
10 West 35 Street, Chicago, Illinois 60616
312/567-4000

January 8, 1981

Mr. Kenneth Axetell, Jr.
PEDCo Environmental, Inc.
Crown Center, Suite 300
2420 Pershing Road
Kansas City, Missouri 64108

Subject: Letter Report on IITRI Project No. C8583
"Microscopical Analysis of St. Joseph TSP"
P.O. No. PEI-80-2938-3450-23

Dear Mr. Axetell:

The microscopical analyses of the 16 high volume filter samples submitted for identification of the total suspended particulate (TSP) have been completed. The samples were collected at five monitoring sites in the St. Joseph, Missouri area.

Analysis methods employed and results obtained are described below. Individual sample analysis reports and photomicrographs are included, respectively, in Appendices A and B.

1. ANALYSIS METHODS

1.1 Samples Submitted

Sixteen samples collected on 8" x 10" glass fiber filter substrates were submitted for analysis, along with a blank filter from that lot. Table 1 lists the samples and meteorological data received. Information as to the sites' relative locations was not provided.

1.2 Low Temperature Ashing Analysis

Precisely measured sections of each filter were desiccated, weighed, and then ashed in a radio frequency generated activated oxygen plasma asher. Ashing time for complete removal of combustible materials was two hours at 550 watts.

Upon removal from the asher, the samples were cooled to room temperature in a desiccator and then weighed to determine the mass lost in ashing. From the mass of particles known to be present on the total filter, the mass of particles present on the portion of the filter ashed was calculated by assuming that the total mass of particles was distributed evenly over the filter's effective collection area (7" x 9"). The mass percent of materials lost in the ashing process (% LTA Loss) was then calculated from the measured mass loss (after the blank value subtraction) divided by the mass of particles assumed to be present on the filter section ashed.

Table 1. SAMPLES SUBMITTED FOR ANALYSIS

SAMPLE NO.	SAMPLE DATE	SAMPLE SITE	LOCATION	TSP ($\mu g/m^3$)	(1) PREVAILING WIND DIRECTION	(2) MEAN WIND SPEED (mph)	(2) DAYS SINCE RAIN (>0.01")	(2) 24-HR PRECIP. TOTAL OF LAST RAIN
360909	9/18/80	1	Lake Rd. STP	134	180°-S	8.2	2	0.38
360934	"	2	Rosecrans Airport	83	"	"	"	"
360933	"	3	Post Office	47	"	"	"	"
360932	"	4	Fire Station	99	"	"	"	"
360931	"	5	Faraon St. STP	54	"	"	"	"
360922	9/30/80	1	Lake Rd. STP	84	270°-W	5.6	6	0.04
360921	"	2	Rosecrans Airport	83	"	"	"	"
360920	"	3	Post Office	102	"	"	"	"
360919	"	4	Fire Station	73	"	"	"	"
360915	10/06/80	2	Rosecrans Airport	146	240°-WSW	11.4	12	0.04
360914	"	3	Post Office	147	"	"	"	"
360912	"	5	Faraon St. STP	118	"	"	"	"
360906	10/12/80	5	Faraon St. STP	157	140°-SE	5.8	18	0.04
360904	10/18/80	1	Lake Rd. STP	58	330°-NNW	7.6	2	0.97
360902	"	3	Post Office	53	"	"	"	"
360901	"	4	Fire Station	40	"	"	"	"

(1) St. Joseph-Rosecrans Airport data (0800-2200). Means checked against KCI 24-hr obs.

(2) KCI data.

1.3 Ion Chromatographic Analyses for Sulfate and Nitrate

A precisely measured section (8 in^2) of each filter was extracted with distilled, deionized water to dissolve water soluble salts. The resulting solution was filtered to remove particles and the remains of the glass fiber filter, and was then brought to a known volume with water. Concentrations of sulfate and nitrate ions in the water extracts were determined by ion chromatography.

The areas under the sulfate and nitrate peaks in the anion chromatogram generated for each sample were measured and converted to ion concentrations in the water extract from standard calibration curves. The raw data were then multiplied by the appropriate extract volume and section area correction factors to yield the masses of ions per 8 in^2 of filter. Mass concentrations of sulfate and nitrate in the TSP could then be calculated from the mass of ions present on a known filter area (minus the blank value) divided by the mass of total particles present on that area of filter.

1.4 Polarized Light Microscopy

Sections of each unashed and ashed high volume filter sample were mounted on glass slides in pools of standard immersion oil ($n_D = 1.515$) under coverslips. The immersion oil rendered the glass fibers invisible, thereby allowing transmission of light and observation of particle types collected on the filter surface and throughout the filter depth.

Particles were identified from physical properties such as morphology, size, surface texture and color, and optical properties such as refractive index, birefringence, and degree of transparency, that were observed by polarized light. The sulfate/nitrate concentrations were converted to the respective ammonium salt concentrations, and this figure was entered on the individual sample analysis report forms. From size, frequency and density data, the remaining particle type concentrations were determined in the ashed (non-combustible particle types) and unashed (combustible particle types) filter sections.

2. ANALYSIS RESULTS

Table 2 summarizes the results of the low temperature ashing and ion chromatography analyses.

The microscopical analysis results are summarized in Table 3. Individual data reports for each sample which list particle type concentrations are attached.

Particle types identified are classified into five major categories which also very roughly group the particles according to emission sources. Minerals are pavement, gravel and soil components that are suspended by traffic, wind, construction, agriculture, etc., as well as materials suspended by bulk mineral handling activities. The mineral sources are usually local but may be long range

Table 2. RESULTS OF ASHING AND CHEMICAL ANALYSES

SAMPLE NO.	SAMPLE DATE	SAMPLE SITE	TSP (μg/m³)	% LTA LOSS	$SO_4^=$ (μg/m³)	NO_3^- (μg/m³)
360939	9/18/80	1	134	35	10.9	3.8
360934	"	2	83	38	21.9	2.7
360933	"	3	47	67	8.1	3.1
360932	"	4	99	32	11.9	3.3
360931	"	5	54	48	9.0	2.2
360922	9/30/80	1	84	17	6.6	2.9
360921	"	2	83	22	5.6	4.1
360920	"	3	102	23	5.1	3.0
360919	"	4	73	24	3.7	3.3
360915	10/06/80	2	146	18	11.1	4.2
360914	"	3	147	15	7.1	2.8
360912	"	5	118	16	7.0	2.6
360906	10/12/80	5	157	30	2.8	0.8
360904	10/18/80	1	58	12	5.3	1.0
360902	"	3	53	25	4.1	0.9
360901	"	4	40	35	3.2	0.9

Table 3. SUMMARY OF MICROSCOPICAL ANALYSIS RESULTS

SAMPLE NO.	SAMPLE DATE	SAMPLE SITE	TSP (μg/m³)	MINERALS		MOBILE VEHICLE EMISSIONS		COMBUSTION PRODUCTS				BIOLOGICALS		MISC.	
								PRIMARY EMISSIONS		AMMONIUM SULFATES & NITRATES					
				MASS %	μg/m³	MASS %	μg/m³	MASS %	μg/m³	MASS %	μg/m³	MASS %	μg/m³	MASS %	μg/m³
360939	9/18/80	1	134	49	66	6	8	15	20	15	20	7	9	7	9
360934	"	2	83	36	30	5	4	7	6	41	34	6	5	4	3
360933	"	3	47	23	11	13	6	11	5	33	16	17	8	2	<1
360932	"	4	99	51	50	12	12	8	8	21	21	3	3	4	4
360931	"	5	54	38	20	7	4	9	5	28	15	13	7	4	2
360922	9/30/80	1	84	61	51	2	2	8	7	15	12	6	5	7	6
360921	"	2	83	61	51	4	3	3	3	16	13	9	7	6	5
360920	"	3	102	63	64	8	8	3	3	11	11	5	5	9	9
360919	"	4	73	65	47	6	4	4	3	13	10	3	2	8	6
360915	10/06/80	2	146	73	107	2	3	1	2	14	20	5	7	4	6
360914	"	3	147	72	106	4	6	2	3	9	13	3	4	9	13
360912	"	5	118	70	83	3	4	2	2	11	13	5	6	8	9
360906	10/12/80	5	157	62	97	7	11	6	9	3	5	12	19	9	14
360904	10/18/80	1	58	71	41	2	1	2	1	15	9	3	2	6	3
360902	"	3	53	60	32	6	3	4	2	13	7	10	5	6	3
360901	"	4	40	53	21	8	3	8	3	14	6	12	5	4	1

transported materials as in the case of dust storms. Particles readily identified as having been emitted by Mobile Vehicles are the rubber tire fragments; vehicle exhaust particles (included in the elemental carbon category on the individual data reports) were present in all samples, but as the very fine exhaust particles could not be readily quantitated separately from the other fine carbonaceous materials emitted by stationary combustion operations, this exhaust component was included in the Combustion Product category. Combustion Products are both primary (directly emitted as particles) and secondary (particles formed in the atmosphere from conversions and reactions of emitted gases) emissions from large and small scale stationary (and mobile, in the case of secondary aerosols and vehicle exhaust) combustion sources; particle emission sources can be both local and long range. Biologicals are mostly natural aerosols, primarily emitted by vegetation. The Miscellaneous category includes the iron oxide and magnetic particle types as well as the raw cement, carbonate agglomerates, and paint component.

3. DISCUSSION OF RESULTS

Mineral particles were the primary components of the samples and represented 23-73% (11 $\mu g/m^3$ - 107 $\mu g/m^3$) of the TSP. Carbonates were the dominant mineral type in all but two (nos. 360906, 360904) of the 16 samples. Although pavement was indicated as a source of the carbonate minerals, the abundance of carbonate particles coated with clays in the samples suggested gravel was a major source of carbonates in the St. Joseph TSP. Concentrations of rubber tire fragments and the heavy carbonate mineral embedment in these fragments indicated traffic was probably the main method of carbonate mineral suspension. However, the presence in one sample of agglomerates of near spherical carbonate mineral particles, suggestive of emission from an industrial or commercial processing or waste handling operation, and the association of these spherical carbonates with fungal conidia indicated traffic may not have been the sole method of carbonate mineral suspension. The spherical nature of the agglomerates indicated the carbonate had crystallized from solution; the association of the spherical agglomerates with fungal conidia suggested impact from a food processing industry or even a sewage treatment plant. Another possible source of carbonates in the St. Joseph TSP was suggested by the presence of raw cement fragments in eight of the 16 samples, most frequently at site 3. That bulk carbonate mineral handling or transport emissions in conjunction with concrete production or construction activities may have impacted the St. Joseph area should be considered.

Quartz mineral particles constituted a significant portion of the mineral population. Quartz particle morphologies and association with clay, as well as the presence of other soil derived minerals (fluorite, micas) in the samples, indicated this mineral matter was suspended from soil or gravel. It could not be determined with certainty, however, whether traffic, construction, or possibly agriculture-related soil disturbing activities were responsible for suspension of the soil minerals.

Emissions from local and non-local stationary combustion sources which burned coal were major contributors to the TSP. Flyash types and sizes indicated local pulverized coal burning operations contributed most of the primary combustion products present. The lack of a strong correlation between primary combustion product and secondary sulfate and nitrate aerosol concentrations suggested local combustion operations were probably not the main source of the secondary aerosols. The very similar concentrations of nitrate from site to site on each date (i.e., within 1.6 μg/m³) suggested that nitrate aerosols were contributed mostly by local mobile and stationary combustion sources. The similar concentrations of sulfate from site to site on 9/30 and 10/18, even though primary combustion products were quite variable in concentration, indicated that a "background" sulfate aerosol impacts the St. Joseph area. Elevated sulfate concentrations at one site on a particular date (especially site 2) indicated occasional impact from a more localized source; therefore, background, transported pollutants cannot be identified as the sole source of the sulfate in the St. Joseph TSP.

Biological aerosols had rather significant impacts on the samples. Fungal spores and conidia and starch grains were especially abundant; this suggested that anthropogenic sources (grain handling, agricultural crop processing) in addition to natural sources contributed these components.

Iron oxides and magnetic fragments were trace to minor components of the samples. Local combustion operations and normal street debris (i.e., metal corrosion products of automobiles and trucks) are likely sources of these components.

Raw cement particles were noted in several samples, particularly those collected at site 3. This component may have been contributed by cement manufacturing or concrete mixing operations.

Spherical particles of white paint were noted in one sample. A local, probably small scale, spray painting operation probably contributed the paint component.

Respectfully submitted,
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Atth.

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360939
TSP ($\mu g/m^3$) 134
SAMPLE SITE 1
SAMPLE DATE 9/18/80

35 % LTA LOSS 8.1 % $SO_4^=$ 2.8 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	12	16	0.2-75
carbonates	25	6	0.2-62
clays, humus	8	9	0.5-133
other	4	14	1-83
asphalt	<1	14	1-50
MOBILE SOURCES			
rubber tire fragments	6	15	1-80
COMBUSTION SOURCES			
glassy flyash	2	3	0.2-50
raw coal fragments	2	7	0.5-30
partially combusted fragments	9	3	1-300
elemental carbon	2	0.2	0.2-1
ammonium sulfates, nitrates	15	-	-
BIOLOGICALS			
pollens, spores, conidia	7	20	
plant hairs and fragments	<1		
insect parts	<1		
starch	<1		
MISCELLANEOUS			
non-magnetic iron oxides	7	4	0.2-63
magnetic fragments	<1		
raw cement	<1		

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360934
TSP ($\mu g/m^3$) 83
SAMPLE SITE 2
SAMPLE DATE 9/18/80

38 % LTA LOSS 26.4 % $SO_4^=$ 3.3 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm) MEAN	PARTICLE SIZE (μm) RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	10	15	0.2-70
carbonates	19	8	0.2-37
clays, humus	4	10	0.5-180
other	3	14	1-98
asphalt	<1	16	1-23
MOBILE SOURCES			
rubber tire fragments	5	16	1-100
COMBUSTION SOURCES			
glassy flyash	3	3	0.2-63
raw coal fragments	<1	14	0.5-40
partially combusted fragments	3	5	1-64
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	41	-	-
BIOLOGICALS			
pollens, spores, conidia	5	20	
plant hairs and fragments	<1		
insect parts	<1		
starch	1	12	
MISCELLANEOUS			
non-magnetic iron oxides	4	5	0.2-55
magnetic fragments	<1		

PROJECT	C8583	SAMPLE NO.	360933
SPONSOR	PEDCo - St. Joseph	TSP (μg/m³)	47
MICROSCOPIST	EBS	SAMPLE SITE	3
REPORT DATE	1/8/81	SAMPLE DATE	9/18/80

67 % LTA LOSS   17.3 % $SO_4^=$ 6.7 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	4	15	0.2-145
carbonates	17	8	0.2-81
clays, humus	1	8	0.5-57
other	1	11	1-90
asphalt	<1		1-30
MOBILE SOURCES			
rubber tire fragments	13	16	1-113
COMBUSTION SOURCES			
glassy flyash	1	3	0.2-63
raw coal fragments	<1	12	
partially combusted fragments	9	5	1-95
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	33	-	-
BIOLOGICALS			
pollens, spores, conidia	2		
plant hairs and fragments	<1		
insect parts	<1		
starch	15	12	
MISCELLANEOUS			
non-magnetic iron oxides	2	3	0.2-57
magnetic fragments	<1		
raw cement	<1		5-35

PROJECT CB583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360932
TSP ($\mu g/m^3$) 99
SAMPLE SITE 4
SAMPLE DATE 9/18/80

32 % LTA LOSS 12.0 % $SO_4^=$ 3.3 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm) MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	8	15	0.2-73
carbonates	37	9	0.2-40
clays, humus	3	10	0.5-59
other	3	14	1-97
asphalt	<1	15	
MOBILE SOURCES			
rubber tire fragments	12	14	1-109
COMBUSTION SOURCES			
glassy flyash	2	3	0.2-30
raw coal fragments	<1	10	
partially combusted fragments	5	3	1-65
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	21	-	-
BIOLOGICALS			
pollens, spores, conidia	3		
plant hairs and fragments	<1		
insect parts	<1		
starch	<1	12	
MISCELLANEOUS			
non-magnetic iron oxides	4	3	0.2-73
magnetic fragments	<1		

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360931
TSP ($\mu g/m^3$) 54
SAMPLE SITE 5
SAMPLE DATE 9/18/80

48 % LTA LOSS   16.6 % $SO_4^=$ 4.1 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (µm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	5	14	0.2-80
carbonates	28	7	0.2-38
clays, humus	3	10	0.5-45
other	2	11	1-85
asphalt	<1		
MOBILE SOURCES			
rubber tire fragments	7	16	1-85
COMBUSTION SOURCES			
glassy flyash	1	3	0.2-45
raw coal fragments	<1	15	0.5-25
partially combusted fragments	7	3	1-102
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	28	-	-
BIOLOGICALS			
pollens, spores, conidia	12	20	
plant hairs and fragments	1		
insect parts	<1		
starch	<1		
MISCELLANEOUS			
non-magnetic iron oxides	4	3	0.2-63
magnetic fragments	<1		

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360922
TSP ($\mu g/m^3$) 84
SAMPLE SITE 1
SAMPLE DATE 9/30/80

17 % LTA LOSS 7.8 % $SO_4^=$ 3.5 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	10	14	0.2-88
carbonates	39	7	0.2-60
clays, humus	5	10	0.5-45
other	7	12	1-70
asphalt	<1		
MOBILE SOURCES			
rubber tire fragments	2	14	1-113
COMBUSTION SOURCES			
glassy flyash	4	4	0.2-30
raw coal fragments	<1		0.5-30
partially combusted fragments	3	3	1-65
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	15	-	-
BIOLOGICALS			
pollens, spores, conidia	6	20	
plant hairs and fragments	<1		
insect parts	<1		
starch	<1	12	
MISCELLANEOUS			
non-magnetic iron oxides	7	4	0.2-89
magnetic fragments	<1		
raw cement	<1		

PROJECT	C8583	SAMPLE NO.	360921
SPONSOR	PEDCo - St. Joseph	TSP ($\mu g/m^3$)	83
MICROSCOPIST	EBS	SAMPLE SITE	2
REPORT DATE	1/8/81	SAMPLE DATE	9/30/80

22 % LTA LOSS 6.8 % $SO_4^=$ 4.9 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	12	14	0.2-122
carbonates	40	8	0.2-73
clays, humus	3	10	0.5-53
other	6	12	1-65
asphalt	<1		
MOBILE SOURCES			
rubber tire fragments	4	14	1-170
COMBUSTION SOURCES			
glassy flyash	<1		
raw coal fragments	<1		
partially combusted fragments	2	3	1-113
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	16	-	-
BIOLOGICALS			
pollens, spores, conidia	7	30	
plant hairs and fragments	2		
insect parts	<1		
starch	<1		
MISCELLANEOUS			
non-magnetic iron oxides	6	3	0.2-135
magnetic fragments	<1		

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360920
TSP ($\mu g/m^3$) 102
SAMPLE SITE 3
SAMPLE DATE 9/30/80

23 % LTA LOSS 5.0 % $SO_4^=$ 2.9 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (µm) MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	13	14	0.2-97
carbonates	41	7	0.2-65
clays, humus	5	9	0.5-65
other	4	12	1-50
asphalt	<1	12	1-43
MOBILE SOURCES			
rubber tire fragments	8	14	1-122
COMBUSTION SOURCES			
glassy flyash	1	4	0.2-25
raw coal fragments	<1		
partially combusted fragments	2	4	1-32
elemental carbon	<1	0.2	0.2-1
ammonium sulfates, nitrates	11	-	-
BIOLOGICALS			
pollens, spores, conidia	3	20	
plant hairs and fragments	<1		
insect parts	<1		
starch	2	12	
MISCELLANEOUS			
non-magnetic iron oxides	7	4	0.2-73
magnetic fragments	<1		
raw cement	2	12	5-50

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360919
TSP ($\mu g/m^3$) 73
SAMPLE SITE 4
SAMPLE DATE 9/30/80

24 % LTA LOSS 5.1 % $SO_4^=$ 4.5 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	13	10	0.2-60
carbonates	41	8	0.2-53
clays, humus	4	9	0.5-45
other	6	8	1-89
asphalt	<1		
MOBILE SOURCES			
rubber tire fragments	6	14	1-162
COMBUSTION SOURCES			
glassy flyash	<1	4	0.2-30
raw coal fragments	<1		
partially combusted fragments	3	3	1-65
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	13	-	-
BIOLOGICALS			
pollens, spores, conidia	3	20	
plant hairs and fragments	<1		
insect parts	<1		
starch	<1		
MISCELLANEOUS			
non-magnetic iron oxides	8	3	0.2-60
magnetic fragments	<1		
raw cement	<1		

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360915
TSP (μg/m³) 146
SAMPLE SITE 2
SAMPLE DATE 10/6/80

18 % LTA LOSS   7.6 % $SO_4^=$ 2.9 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	12	15	0.2-89
carbonates	46	7	0.2-75
clays, humus	9	10	0.5-72
other	6	13	1-80
asphalt	<1		
MOBILE SOURCES			
rubber tire fragments	2	13	1-85
COMBUSTION SOURCES			
glassy flyash	<1	4	
raw coal fragments	<1		
partially combusted fragments	1	3	1-80
elemental carbon	<1	0.2	0.2-1
ammonium sulfates, nitrates	14	-	-
BIOLOGICALS			
pollens, spores, conidia	5	25	
plant hairs and fragments	<1		
insect parts	<1		
starch	<1		
MISCELLANEOUS			
non-magnetic iron oxides	4	5	0.2-126
magnetic fragments	<1		
raw cement	<1		

PROJECT	C8583	SAMPLE NO.	360914
SPONSOR	PEDCo - St. Joseph	TSP ($\mu g/m^3$)	147
MICROSCOPIST	EBS	SAMPLE SITE	3
REPORT DATE	1/8/81	SAMPLE DATE	10/6/80

15 % LTA LOSS   4.8 % $SO_4^=$ 1.9 % NO_3^-

		PARTICLE SIZE (µm)	
COMPONENT	CONCENTRATION (MASS %)	MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	12	15	0.2-133
carbonates	45	7	0.2-95
clays, humus	8	10	0.5-55
other	7	12	1-210
asphalt	<1		
MOBILE SOURCES			
rubber tire fragments	4	15	1-100
COMBUSTION SOURCES			
glassy flyash	<1	3	0.2-25
raw coal fragments	<1		
partially combusted fragments	2	4	1-70
elemental carbon	<1	0.2	0.2-1
ammonium sulfates, nitrates	9	-	-
BIOLOGICALS			
pollens, spores, conidia	3		
plant hairs and fragments	<1		
insect parts	<1		
starch	<1	12	
MISCELLANEOUS			
non-magnetic iron oxides	9	5	0.2-60
magnetic fragments	<1		
raw cement	<1		5-25

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81
SAMPLE NO. 360912
TSP ($\mu g/m^3$) 118
SAMPLE SITE 5
SAMPLE DATE 10/6/80

16 % LTA LOSS　　5.9 % $SO_4^=$　　2.2 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm) MEAN	PARTICLE SIZE (μm) RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	14	14	0.2-75
carbonates	41	6	0.2-43
clays, humus	9	9	0.5-80
other	6	11	1-75
asphalt	<1		
MOBILE SOURCES			
rubber tire fragments	3	12	1-68
COMBUSTION SOURCES			
glassy flyash	<1	5	
raw coal fragments	<1		
partially combusted fragments	2	3	1-47
elemental carbon	<1	0.2	0.2-1
ammonium sulfates, nitrates	11	-	-
BIOLOGICALS			
pollens, spores, conidia	5	10	
plant hairs and fragments	<1		
insect parts	<1		
starch	<1		
MISCELLANEOUS			
non-magnetic iron oxides	8	4	0.2-48
magnetic fragments	<1		

PROJECT CB583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81
SAMPLE NO. 360906
TSP ($\mu g/m^3$) 157
SAMPLE SITE 5
SAMPLE DATE 10/12/80

30 % LTA LOSS   1.8 % $SO_4^{=}$ 0.5 % NO_3^{-}

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (µm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	30	15	0.2-65
carbonates	20	6	0.2-41
clays, humus	6	12	0.5-60
other	6	10	1-75
asphalt	<1		
MOBILE SOURCES			
rubber tire fragments	7	12	1-81
COMBUSTION SOURCES			
glassy flyash	<1		0.2-15
raw coal fragments	<1		
partially combusted fragments	5	4	1-33
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	3	-	-
BIOLOGICALS			
pollens, spores, conidia	9		
plant hairs and fragments	1		
insect parts	<1		
starch	2		
MISCELLANEOUS			
non-magnetic iron oxides	4	3	0.2-57
magnetic fragments	<1		
carbonate agglomerates	5	4	

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360904
TSP ($\mu g/m^3$) 58
SAMPLE SITE 1
SAMPLE DATE 10/18/80

12 % LTA LOSS 9.2 % $SO_4^=$ 1.7 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	38	16	0.2-95
carbonates	19	9	0.2-55
clays, humus	7	11	0.5-78
other	7	12	1-100
asphalt	<1		1-60
MOBILE SOURCES			
rubber tire fragments	2	14	1-100
COMBUSTION SOURCES			
glassy flyash	<1		0.2-20
raw coal fragments	<1		
partially combusted fragments	2	3	1-85
elemental carbon	<1	0.2	0.2-1
ammonium sulfates, nitrates	15	-	-
BIOLOGICALS			
pollens, spores, conidia	2	20	
plant hairs and fragments	1		
insect parts	<1		
starch	<1	12	
MISCELLANEOUS			
non-magnetic iron oxides	6	3	0.2-140
magnetic fragments	<1		
paint spheres	<1	30	10-60

PROJECT C8583
SPONSOR PEDCo - St. Joseph
MICROSCOPIST EBS
REPORT DATE 1/8/81

SAMPLE NO. 360902
TSP ($\mu g/m^3$) 53
SAMPLE SITE 3
SAMPLE DATE 10/18/80

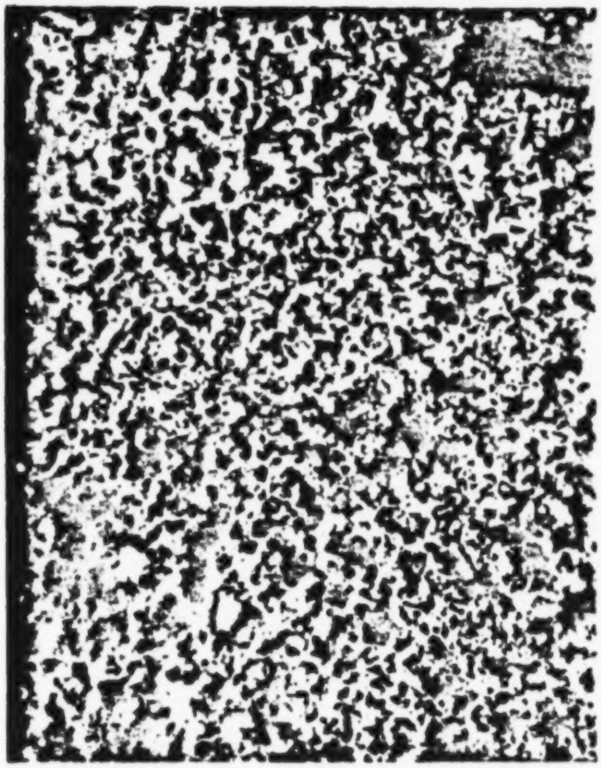
25 % LTA LOSS 7.8 % $SO_4^=$ 1.7 % NO_3^-

COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (μm) MEAN	PARTICLE SIZE (μm) RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	21	16	0.2-108
carbonates	31	8	0.2-58
clays, humus	4	10	0.5-115
other	4	13	1-80
asphalt	<1		1-45
MOBILE SOURCES			
rubber tire fragments	6	15	1-170
COMBUSTION SOURCES			
glassy flyash	<1	5	0.2-32
raw coal fragments	<1		
partially combusted fragments	3	4	1-133
elemental carbon	1	0.2	0.2-1
ammonium sulfates, nitrates	13	-	-
BIOLOGICALS			
pollens, spores, conidia	4	20	
plant hairs and fragments	1		
insect parts	<1		
starch	5	12	
MISCELLANEOUS			
non-magnetic iron oxides	6	5	0.2-60
magnetic fragments	<1		
raw cement	<1		

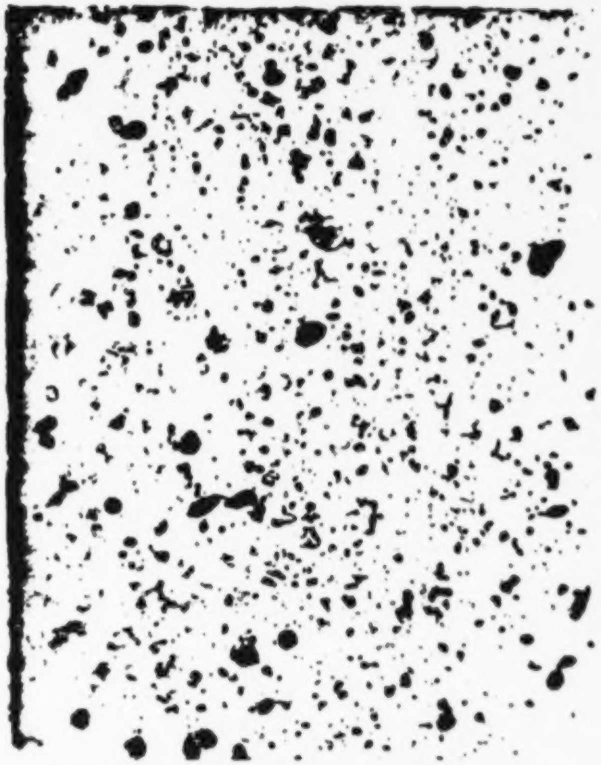
PROJECT	C8583	SAMPLE NO.	360901
SPONSOR	PEDCo - St. Joseph	TSP ($\mu g/m^3$)	40
MICROSCOPIST	EBS	SAMPLE SITE	4
REPORT DATE	1/8/81	SAMPLE DATE	10/18/80

35 % LTA LOSS   8.0 % $SO_4^=$ 2.3 % NO_3^-

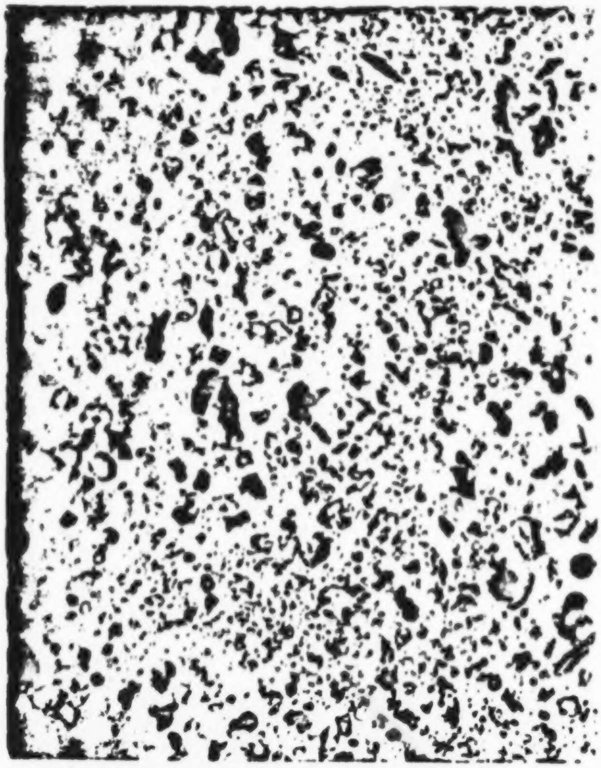
COMPONENT	CONCENTRATION (MASS %)	PARTICLE SIZE (um)	
		MEAN	RANGE, MIN.-MAX.
MINERALS			
quartz and feldspars	14	15	0.2-105
carbonates	34	8	0.2-58
clays, humus	2	10	0.5-45
other	3	14	1-83
asphalt	<1		1-30
MOBILE SOURCES			
rubber tire fragments	8	15	1-150
COMBUSTION SOURCES			
glassy flyash	<1	4	0.2-13
raw coal fragments	<1		
partially combusted fragments	6	3	1-65
elemental carbon	2	0.2	0.2-1
ammonium sulfates, nitrates	14	-	-
BIOLOGICALS			
pollens, spores, conidia	9	10	
plant hairs and fragments	2		
insect parts	<1		
starch	1	12	
MISCELLANEOUS			
non-magnetic iron oxides	4	3	0.2-40
magnetic fragments	<1		



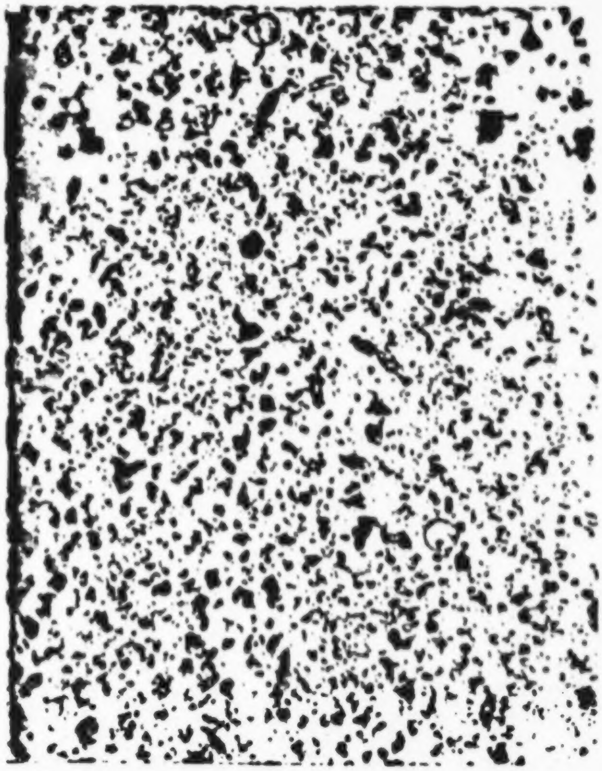
#360939 The abundant coal combustion products (most black particles) obscure view of other sample components.



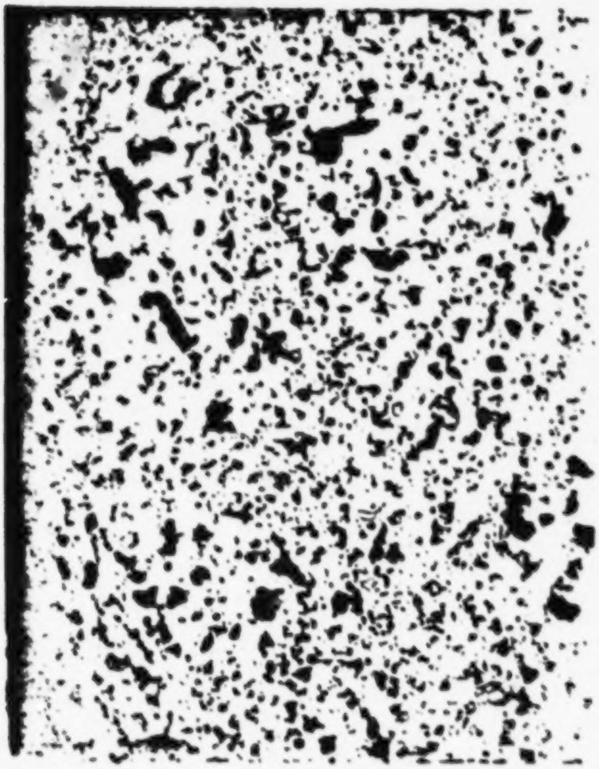
#360934 Few particles are seen because primary components-sulfates & nitrates-are distributed throughout filter depth.



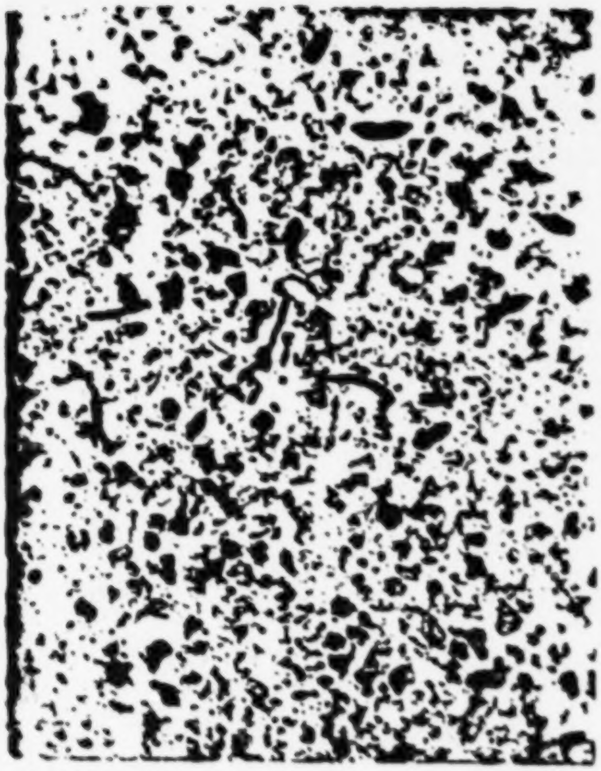
#360933 Elongated black particles are rubber tire fragments; arrows point to starch grains.



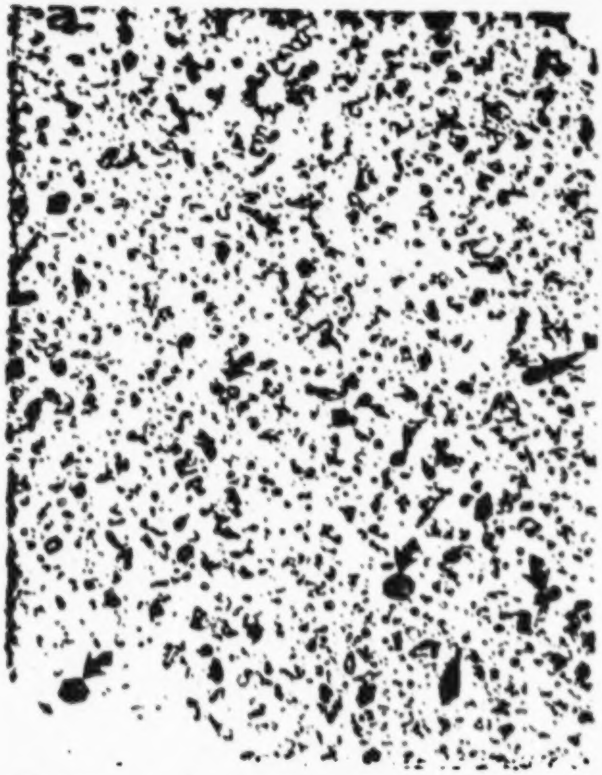
#360932 White particles are carbonate minerals; black particles are rubber tire fragments & coal combustion products.



#360931 Carbonates again dominate the mineral population.

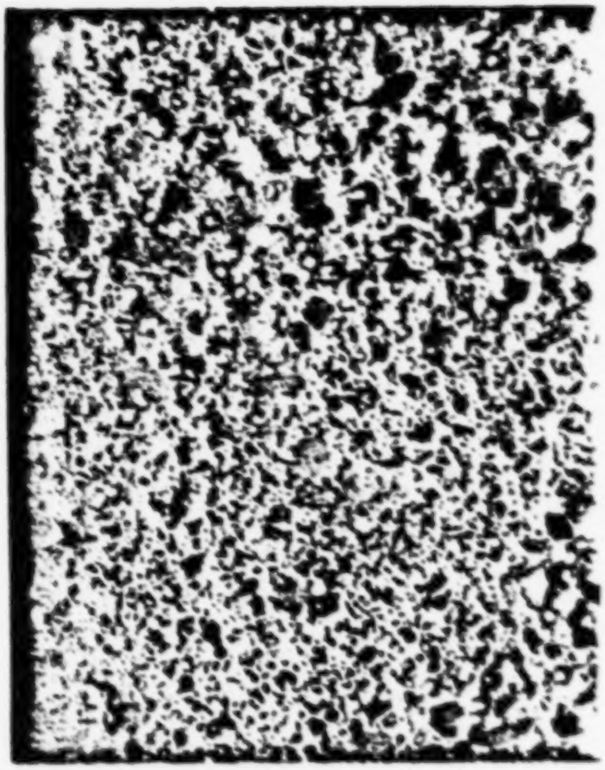


#360922 Arrows point to quartz (white) particles, a raw cement fragment, and flyash spheres.



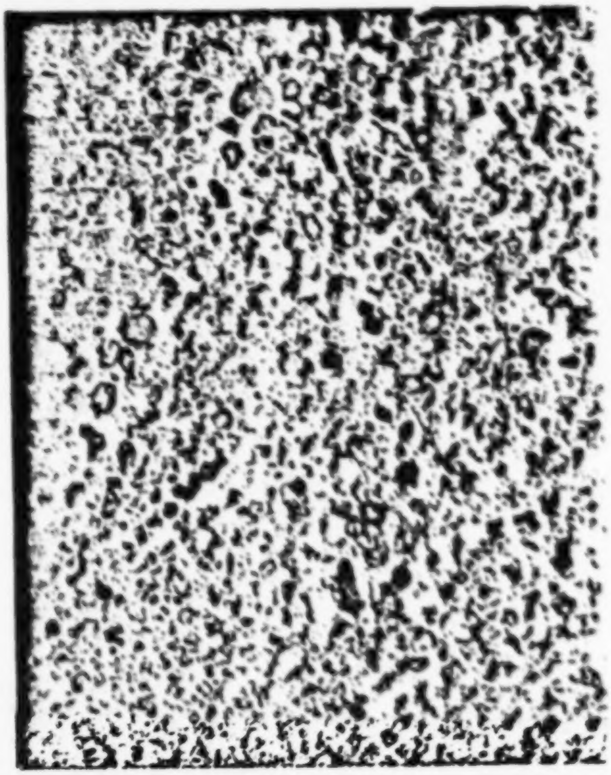
#360921 Biological materials-fungal conidia and (arrows) spores-are numerous; carbonates dominate mineral matter.

#360920 Arrows point to quartz and (gray) clay-coated quartz particles; white fibrous particle is a plant hair.

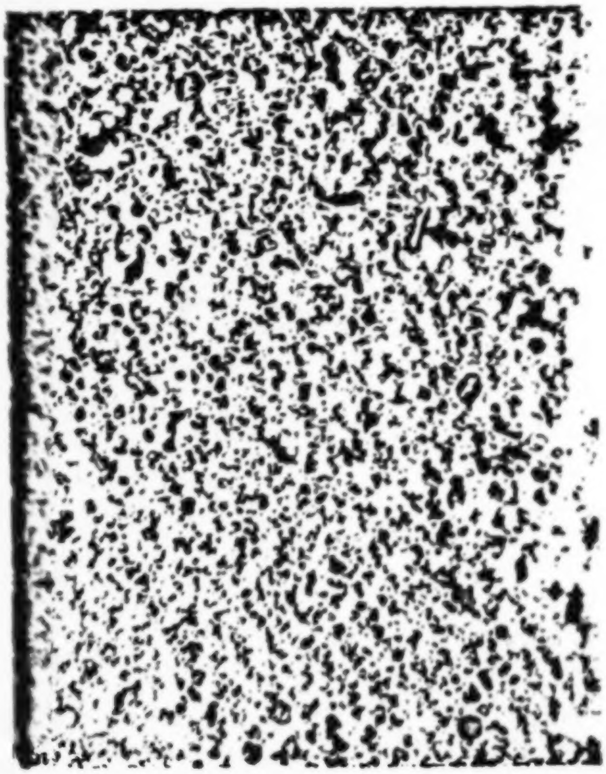


#360919 Arrows point to clay-coated carbonate mineral particles; large black particles are rubber tire fragments.

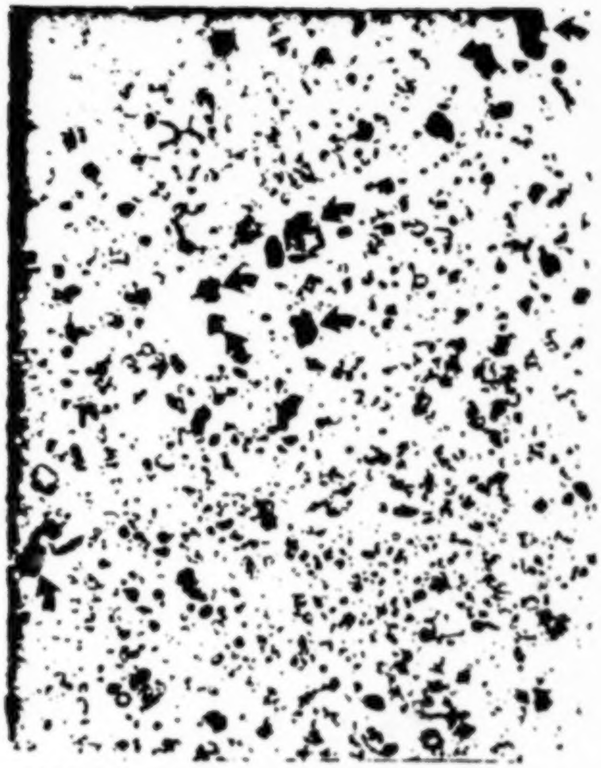
#360915 Largest black particle is humus fragment; fungal spores and conidia are numerous.



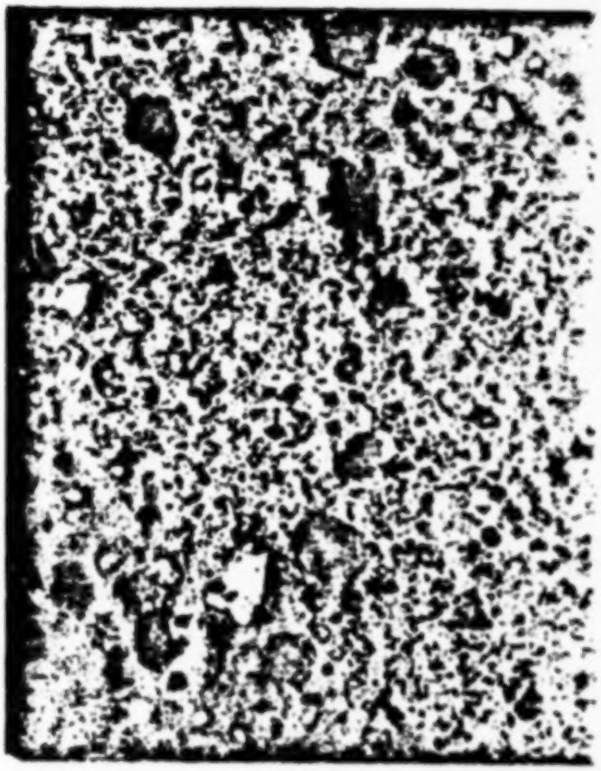
#360914 Carbonate minerals are abundant here; note the presence of rubber tire fragments.



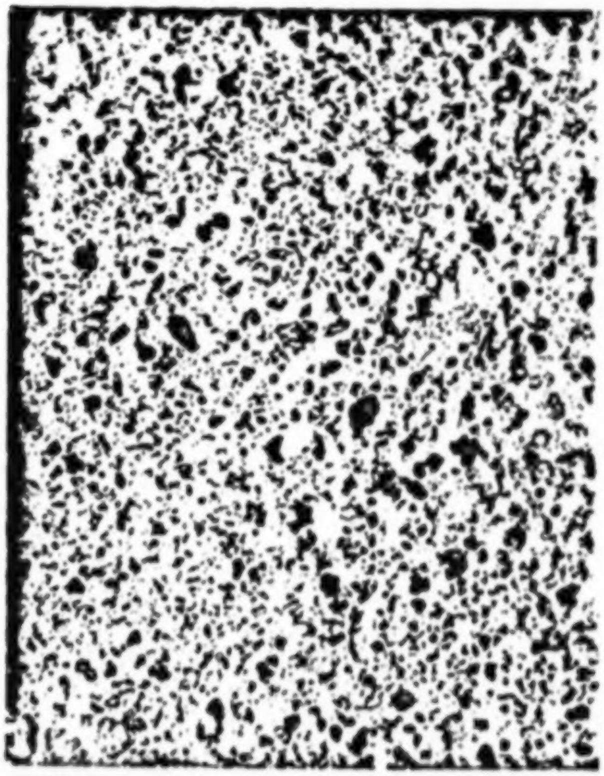
#360912 Minerals present are mostly carbonates; arrow points to clay-coated fluorite particle.



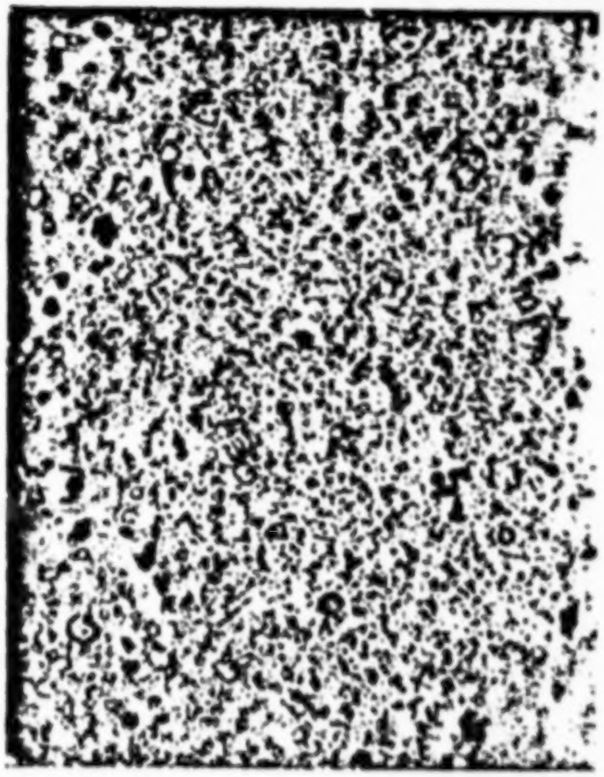
#360906 Arrows point to clay-coated quartz particles & clay agglomerates; large black particles are tire fragments.



#360904 Some of the larger particles collected are shown; arrows point to quartz minerals--most others are carbonates.



#360902 Both carbonate and quartz mineral particles are present; tire fragments are numerous here.



#360901 Minerals present are mostly carbonates; numerous spores can be seen.